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(June 1943)

The Editorial Committee of the Imperial Council of Agricultural Research, India, takes no responsibility for the opinions expressed in this Journal

WATER REQUIREMENT OF *RABI JOWAR* IN THE SCARCITY TRACTS OF THE BOMBAY-DECCAN

By N. V. Kanitkar, M.Ag., B.Sc., Chief Investigator, Bombay Dry Farming Research Scheme, R. B. Gode, M.Sc., First Senior Assistant in charge of Plant Section, and D. H. Gokhale, M.Ag., B.Sc., Second Senior Assistant in Plant Section

(Received for publication on 17 April 1942)

(With Plates IX & X and one text-figure)

Jowar (*Andropogon Sorghum*) occupies the foremost place among the cereal crops of the Bombay Province. Out of the total area of 20 million acres under cereals and pulses in the whole Province of Bombay the area under *jowar* fluctuates between 8 and 10 million acres from year to year. There are two distinct types of this crop, one grown during the *kharif* and the other during the *rabi* season. Of these, the *rabi* types are the most important and form 60 to 70 per cent of the total area under *jowar*. The major area of *rabi jowar* is in the scarcity tract being 5·04 million acres during 1939-40. Practically, the whole of this is entirely dependent on rains which are extremely precarious and unfavourably distributed in these tracts of Bombay. The *jowar* crop serves the dual purpose of providing staple food grain for the people and straw for the cattle.

The average annual rainfall varies from 20 to 27 in. in different parts of the dry tracts of the Bombay-Deccan. It is computed by Mann [1925] that this tract covers an area of nearly 26,000 square miles and forms a plateau with gentle undulations. The rainfall is dissipated in various ways such as surface runoff, evaporation, underground drainage, etc. and this makes successful production of *rabi jowar* extremely uncertain.

As soil moisture is the most dominant factor in the dry areas, the question of the water requirement of crops grown in these areas naturally assumes great importance. Previous work on this subject in India is only limited and the environmental conditions under which it was carried out were entirely different from those in scarcity tracts of Bombay. Again as far as the *jowar* crop is concerned, the varieties of which the water requirement was studied by Leather [1910, 1911] at Pusa were early-monsoon or *kharif*—varieties which were more suitable for fodder than for grain.

It was therefore thought essential to take up the work of determining the water requirement of the most important crop, viz. *rabi jowar*, grown in the scarcity tracts of the Bombay Province and this was included in the programme of work of the Dry Farming Research Scheme at Sholapur. The main objects of this work were (1) to determine the water requirement of the *jowar* plant, (2) to ascertain how far it differs in different varieties, (3) to determine to what extent it is affected by manure and fertilizer applications, etc. With these objects in view, experiments were carried out at Sholapur for a period of seven years from 1934-35 to 1940-41 and these are described and discussed in this paper.

Review of literature

A good deal of work has been done in Europe and America on the water requirement of crops both from the scientific and applied points of view. Kiesselbach [1916] mentions a list of investigators who have reviewed more or less critically the nature and character of the previous work. According to him, Burgerstein recorded in 1904 as many as 394 publications concerning transpiration. In the present review, some of the important lines of investigations on the subject of water requirement are indicated with special reference to the matter herein reported.

Jowar *and other crops*

Literature on the water requirement of *jowar* or sorghum is comparatively rare and what is available has been done generally in comparison with corn or maize. The water requirement of sorghums was determined by Briggs and Shantz [1914] from 1910 onwards along with that of a variety of other plants. Their data in an abbreviated form have been reproduced by Maximov [1929] in connection with the efficiency of transpiration. These investigators found that amongst sorghum varieties the transpiration ratio varies from 285 to 467 while the average value for the genus was 322.

Similar studies were made by Leather [1910] under Indian conditions at Pusa. The water requirement ratio obtained by him for *kharif jowar* from duplicate pots was $360 \cdot 5 \pm 90 \cdot 5$. Kiesselbach [1916, 1926 and 1929] made an exhaustive study of the water requirement of corn and compared the results with those of sorghum and sunflower. As a result of his investigations, he concludes that the water requirement ratio does not appear to be a very important index as

to the relative suitability of various crops to any particular region or a set of conditions. There doubtless are other important factors and economic reasons for the relative excellence or choice of crops.

Miller and Coffman [1918] studied the comparative transpiration of corn and sorghums and found that the former transpired more water and that a small leaf-surface was an important factor in reducing the water loss. Recently, Singh and his collaborators [1935] determined in India the water requirement of about a dozen crops but among these *jowar* was not included. They found, among other things, that the length of the life-cycle exercised in general great influence on the water requirement of varieties. In effective varieties, the life-cycle seemed to cut short and reduce the use of water to a minimum.

The effects of hybridization on water requirement was also investigated by Briggs and Shantz [1915, 1]. They found that the chances were even that a maize hybrid would not depart in its water requirement by more than 6 per cent from the parental mean.

An important point in connection with the study of the water requirement of plants was raised by Weaver and Crist [1923]. They argued that the soil used hitherto in potometric study failed to represent its normal structure and hence the water requirement of plants with this soil must essentially differ from that under field conditions. They, therefore, used undisturbed soil and determined the water loss of a number of grasses but did not point out the extent to which their transpiration coefficients agreed or differed from those of other investigators.

Effect of manures

The study of the effect of manures on the water requirement of plants dates as far back as 1699. In that year, according to Widtsoe [1920], Woodward conducted experiments on transpiration and reached the conclusion that the amount of water required per pound of dry matter was less if the solution had the proper concentration and contained the elements necessary for plant growth. Sorauer [1883] found that less water per pound of dry matter was required if the soil was fertilized. In 1883, Hellriegal laid down the law that poor plant nutrition increased the water cost per pound of dry matter. Gardner [1908] worked on the manuring of soils and drew pointed attention to the necessity of employing manures in dry farming practices. Similar results were obtained by Leather [1911]. He used no organic manures but with fertilizer applications he obtained a reduction in the transpiration ratio. With *jowar*, however, no such reduction was observed. Montgomery and Kiesselbach [1912] published their earlier results on the water requirement of corn. They observed that the transpiration ratio of corn increased when the soil fertility was decreased.

Effect of climatic factors

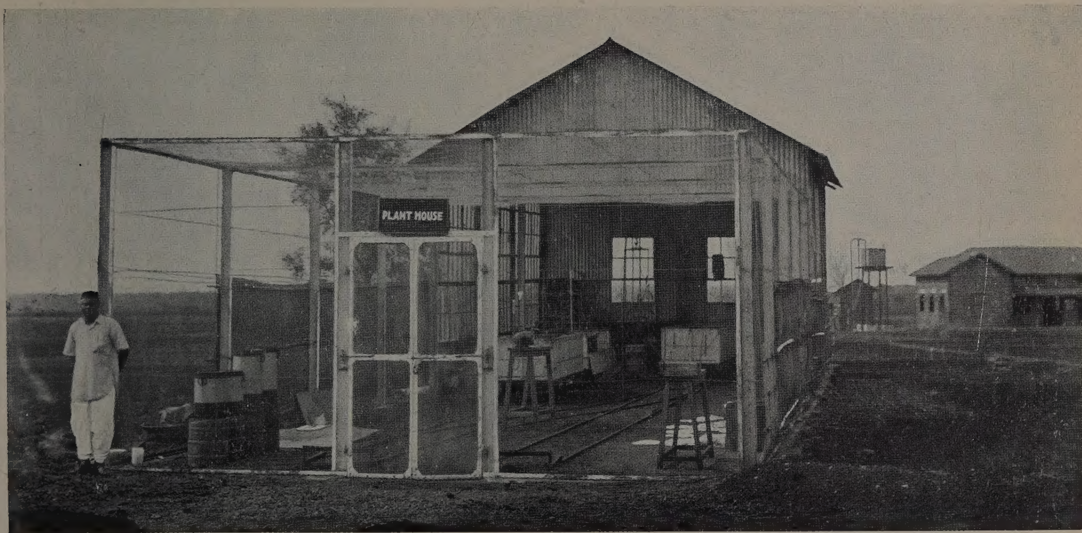
Montgomery and Kiesselbach [1912] observed that the transpiration coefficient of corn changed from 191 to 340 when the humidity was decreased. Kiesselbach [1929] found that the seasonal climatic changes influenced water requirement more than any ordinary variations in soil moisture, culture or variety and that transpiration was as good as evaporation from free water surface.

Briggs and Shantz [1916, 1 and 1916, 2] studied the effect of different meteorological factors on the water requirement of plant and obtained high correlation coefficients between transpiration on the one hand and radiation, temperature and wet-bulb depression on the other. They devised and used elaborate automatic platform scales in studying the march of transpiration with the different meteorological factors [1915, 2]. They found that under conditions favouring high evaporation, plants did not respond wholly as free evaporating systems even when bountifully supplied with water. According to them, water requirement was not correlated with any condition of environment since plants responded differently to varying factors of environment. Cool-weather crops, they state have as a rule low water requirement in cool seasons while with the warm-weather crops the reverse usually holds, although the effect is less marked. Sorghum belongs to the group of warm weather crops and its water requirement decrease with higher temperature.

Inamdar and Dabral [1930] studied the daily water balance of plants. They pointed out that there was a limit beyond which transpiration could not rise though the evaporation rates might continue to soar high, being limited by such factors as the water losing capacity of the evaporating surface, the water absorbing capacity and the rate at which water would be supplied to the evaporating surface.

METHOD AND MATERIALS USED

The studies here reported were carried out in a specially constructed plant-house, situated in the centre of the Dry Farming Research Station. It was 20 ft. in breadth and 70 ft. in length. A part of this house was converted into a shed where the trolleys carrying potometers were shifted on rails to protect them from rains (Plate IX, fig. 1). The direct heating of the potometers was prevented by providing the trolleys with wooden boxes and by closing their open tops with thick white oil cloth covers. The potometers belonged to an earthenware type with a tubular at the bottom and having a diameter of 12 in. and a height of 18 in.



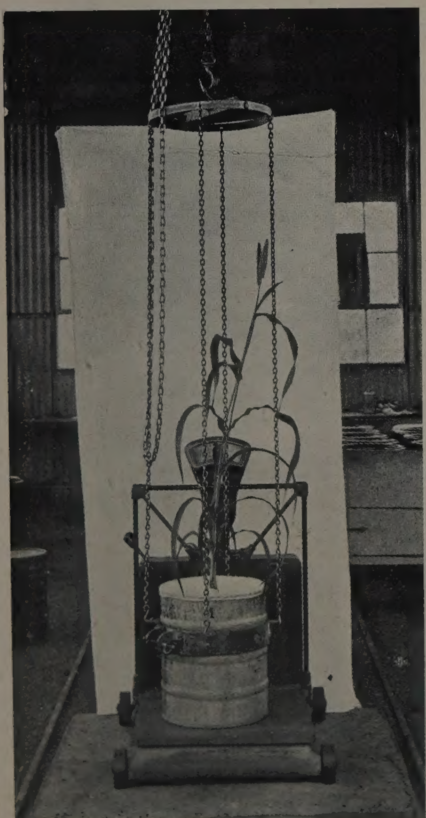


FIG. 1.
Plant-house at Sholapur Dry Farm

FIG. 2.
Avery balance and the arrangement for lifting pots

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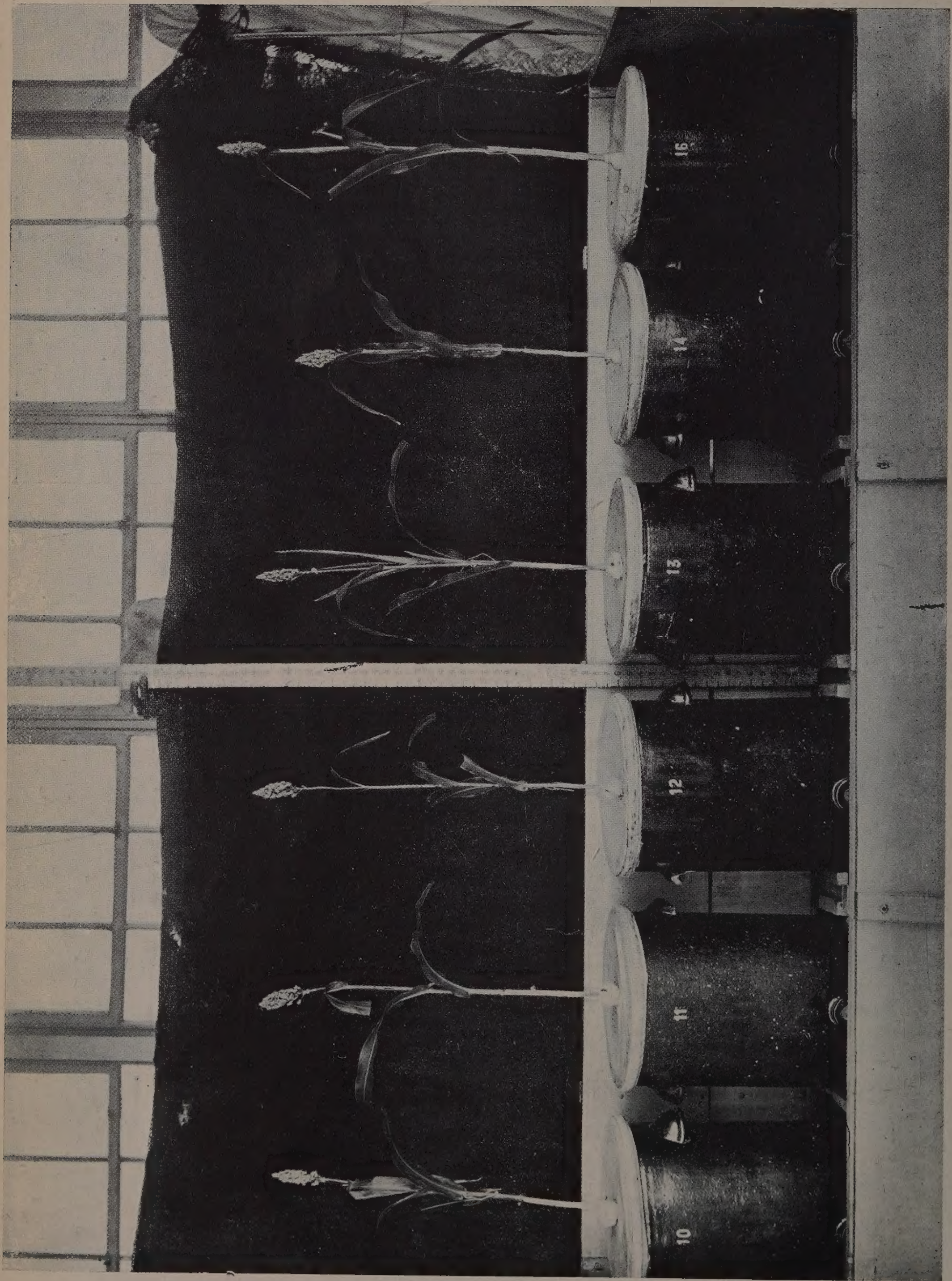

FIG. 1. Battery of pots showing plant growth in the plant-house, in experiments conducted on water requirement at Sholapur

At the time of weighing, they were removed from the trolleys with the aid of a chain and pulley arrangement and weighed on an Avery platform balance of the 'predetermined' type which could weigh correctly to half-an-ounce (Plate IX, fig. 2).

Soil type

There are three types of soil on the area of the experimental station, viz. the light shallow, the medium deep and the deep, being roughly in the proportion of 2 : 2 : 1. Out of these, one standard soil, viz. the medium deep, was used throughout in all experiments except where the effect of different soil types was investigated.

This standard soil has an average depth of about 15 in. but may vary from 9 to 18 in. The soil is dark brown in colour and has a compact constitution. No distinct change is visible in its colour or constitution throughout the whole thickness. It is underlaid by disintegrated trap or *murum* which ensures drainage. The mechanical composition of this soil shows that it belongs to the heavy clay type and has a high retentivity for moisture, while its chemical composition reveals that it is fairly fertile, with a good supply of lime though its nitrogen content is low. Although the soil has got a high moisture equivalent, the high hygroscopic coefficient indicated by the hygroscopic moisture at 50 per cent relative humidity, shows that a great proportion of its moisture is unavailable for plant use. Some important data regarding the character of the soil are given in Table I.

TABLE I

Mechanical and chemical composition and some single value properties of the medium deep soil

(Expressed as per cent on oven-dry matter)

Soil layer in inches	Mechanical composition		Chemical composition					Single value properties		
	Silt	Clay	Lime CaO	Magnesia MgO	Potash K_2O	Phosphoric acid P_2O_5	Nitrogen	Moisture equivalent	Sticky point	Hygroscopic moisture at 50 per cent relative humidity
0 to 9	26·86	58·49	1·48	0·35	0·44	0·06	0·04	43·6	57·8	8·79
9 to 18	26·33	58·60	2·32	0·79	0·48	0·05	0·04	45·3	59·2	8·38

Filling potometers

Every year, the soil from the top (0—9 in.) layer was removed from an untreated field in the month of May, passed through a sieve of half-inch mesh and preserved till required in the *rabi* season. The potometers were filled in September with this soil equivalent to 70 lb. on oven-dry basis. The soil had one inch of *murum* layer at the bottom which formed the substratum as under natural conditions. Prior to filling, the tubulars were closed with corks of suitable size. The soil was then superimposed by one-inch layer of medium-sized sand, well washed of all adhering earth.

Irrigating the potometers and water used

Clean water from the farm well was used in all experiments. The water contained only 40 parts of total salts per 100,000 parts of water. Most of these were made up by Ca, Mg, CO_3, SO_4 and Cl radicals. There was no alkalinity or other sodium salts. Water was evenly distributed by a water-can over the surface layer of sand referred to before and the soil beneath was brought to the saturation point, the small excess being removed through the tubular at the bottom. Further irrigations later in the midst of the season were done in a like manner. This method of watering at the surface was considered to be suitable as it approached natural soil-wetting by showers of rain in the field.

Controlling evaporation of soil moisture

The loss of soil moisture by evaporation was controlled by closing the open tops of the potometers with oil-cloth covers and by interposing circular discs of celotex in between the covers and the sand layer. This latter device prevented the heating of surface soil and reduced the evaporation of soil moisture. Both the oil-cloth cover and the celotex disc were provided with circular openings for allowing the plants to come up and grow freely.

Time of sowing

Pure *jowar* strains evolved at the Mohol *Jowar* Breeding Station were obtained for the conduct of the experiments. Seeds from a single selfed ear-head were employed. When the moisture in the surface layer of the soil became suitable to form a good seed bed, three seeds were sown in the centre of each potometer at a depth of $2\frac{1}{2}$ in. In the first year, sowing was done on 13 October, 1934, and in the succeeding years it was done on 1 October.

Observations and measurements

As transpiration was found to be negligible during the first month after sowing, all the three seedlings were allowed to grow and were thinned to two and finally to one by the end of October. In the first year however two plants were retained in each pot throughout the experiments. The results for first year given later are for two plants. At the time of final thinning, water was added if necessary and the potometers were closed with the celotex discs and oil-cloth covers referred to before. The circular openings in the centre of the oil-cloth covers were fitted with collar and button arrangement for closing. The open space between the plant and the collar was closed with a cotton plug. In the experiments described hereafter four to six replications were used. Suitable controls without plant were also maintained.

Determination of the loss of water by transpiration, measurements of height of the plant, number of leaves, leaf area, etc. were started from 1 November except in the first year and continued till maturity of the plant. In the first year this work was commenced from 3 December.

Measuring leaf area

During the first three years leaf area was measured by the method of Patel and Patel [1922]. In the following years, this was done by the method of Montgomery [1911] by taking three-fourths the product of the maximum length and the maximum breadth of the leaf. This latter method was found to be more accurate and closely approached the results recorded by the actual measurement of leaf area with the aid of a planimeter. This will be evident from the data obtained by the three methods and given in Table II. The Montgomery's method is besides less laborious and easy to work with.

CLIMATIC FACTORS

Meteorological observations were taken four times during the day in a well-equipped observatory near the plant-house in the centre of the farm. The actual data for five months from October to March in each of the seven years are summarized in Table I in the Appendix.

TABLE II

Comparison of different methods for measuring lea area of the jowar *plant*

(Area in sq. cm.)

Leaf number from bottom	Patel and Patel	Planimeter	Montgomery
9th	58·2	62·8	55·1
10th	137·0	176·8	165·0
11th	191·5	207·1	229·5
12th	143·9	188·5	159·5
13th	138·6	145·5	143·4
14th	118·0	132·2	135·0
15th	83·0	95·4	106·3
16th	32·0	40·1	48·0
Total area for the plant	902·6	1048·4	1041·7

It may be pointed out that the average rainfa at Sholapur is 26·60 in. while the rainfall durin the seven years, i.e. 1934-35 to 1940-41, varie from 13·86 to 37·30 in. Of the seven years, or year was characterized by great excess of rainfa and two years by great deficit. The remainin four years had rainfall much near the norma Major portion of the annual rainfall is usual received during the four months from June September. As these experiments were conducte during the *rabi* season from October to March t rainfall during that period has been shown in separate column in Table I in the Appendix, though the rainfall had no direct influence on t plants as the experiments were carried out in t plant-house under protection from rainfall. Oth meteorological factors like temperature, humidit wind velocity, etc. are also given only for the peri of the experiments. If the meteorological da of the last two years, viz. 1939-40 and 1940- which were characterized by the lowest and t highest performance of the plants in the pla house respectively, are compared, it is seen that t year of good performance, viz. 1940-41, w marked by higher temperatures, lower solar rad tion and hours of sunshine, higher relative hu dity, lower wind velocity and lower evaporati from free water surface as compared with those the year 1939-40 with the smallest plant growth

PRESENTATION OF DATA

Experiment I. Water requirement of jowar

In this experiment the *jowar* variety used longed to the loose ear-head type and the str M-47-3 evolved at Mohol *Jowar* Breeding Stat was used in all years. The water requirement this variety was determined for a period of se years. In this set of experiments, water was ad only when the plants showed signs of tempor

ilting. Water was required to be added, to bring ne moisture to the starting level, only on one or wo occasions during the whole life-history of the lant in the first six years. In the last year, on ac-ount of extremely good development of the plant third watering became necessary. The total uantity of water present in the soil added at the eginning of the experiment proved insufficient to omplete the life-cycle of *jowar* plant as the pots ould hold only a limited quantity of soil. The oil used in this experiment was the standard type, iz. the medium deep from Sholapur.

The results of seven years showing the total uantity of water lost from the pots with plants nd from pots without plants, along with the eight of shoot and roots produced by the plant e given in Table III. The water requirement f a plant is usually indicated by the transpiration oefficient which is the ratio of water transpired rough the plant to the total dry weight of the lant. This has been calculated and given in the st two columns in the same table, both on the oot basis as well as on the basis of shoot and root ombined.

The results reproduced above bring out the following important points : (1) The time required for completion of the life-history of the *jowar* plant in the seven seasons varied from 16·5 weeks to 21 weeks. (2) The average total quantity of water transpired from each pot was a little more than 18 lb. (3) In spite of all precautions to control direct evaporation, nearly 23·5 per cent of the total loss was due to this factor. (4) The average dry weight of the plant without roots during six years amounted to 20·48 gm. and that of the plant with roots to 23·0 gm. (5) The average transpiration coefficient for six years was 424·7 on shoot basis and 374·3 on the basis of shoot and root combined. As already indicated before, in the first year there were two plants in each part and the dry matter in that year was from two plants and hence results for six years excluding the first are separately given. (6) The transpiration coefficient varied widely during the six years from 300 to 516 on shoot basis. In spite of all precautions to keep all conditions as uniform as possible during the six years, the average total dry matter production of the individual plant varied from

TABLE III

Transpiration coefficients of jowar *variety M-47-3 in the medium deep soil at Sholapur during the period of 7 years*

(Transpiration in oz. and dry matter in gm.)

Year	No. of replications averaged	No. of weeks required for maturity	Total loss of water	Loss of water from controls	Loss of water by transpiration	Dry weight of shoot	Dry weight of roots and shoot together	Transpiration coefficient: On shoot basis	Transpiration coefficient: On shoot *plus* root basis
934-35 * .	4	21·0	413·75	112·37	301·37	18·03	20·39	482·70± 37·92	425·15±38·80
935-36 .	6	17·5	321·83	63·95	257·87	16·58	18·94	450·40±26·04	392·3 ±16·41
936-37 .	6	20·3	378·49	84·23	294·26	20·19	22·67	421·30±22·51	375·6 ±21·29
937-38 .	6	20·5	396·06	93·75	302·31	16·89	20·84	516·80±23·15	417·61±14·36
938-39 .	6	18·8	405·47	79·96	325·51	18·25	19·96	514·95±29·18	470·93±27·96
939-40 .	6	16·5	213·20	73·00	140·20	13·40	14·32	300·40±17·74	282·0 ±17·14
940-41 .	5	17·0	575·60	127·60	448·00	37·62	42·14	344·70±17·60	307·6 ±15·3
Average of seven years	..	18·94	386·30	90·69	295·64	20·14	22·75	433·03	383·59
verage of last six years	..	18·43	381·77	87·08	294·68	20·48	23·06	424·7	374·3

* In 1934-35, there were two plants in each potometer while in other years there was only one plant in ach potometer

14·32 to 42·14 gm. (7) The year 1939-40 with the lowest weight of the plant was the year of the lowest transpiration coefficient or the year of the most efficient and economic plant production. (8) The next best year of low coefficient and economic plant production was the year 1940-41, in which the highest weight of the plant was obtained. (9) The effect of individual meteorological factors on plant performance was not clearly discernible, although the total seasonal effect due to combination of several factors was the most pronounced.

These results indicate that if a *jowar* crop weighing one ton (consisting of one-third ton of grain and two-thirds ton of straw) is to be raised from an acre of land containing soil of medium fertility, i.e. medium deep soil, the average quantity of water utilized to produce the same would be nearly 4·25 in. of rainfall. This may, however, vary from 3 to 5 in. of rainfall in different years. The fact that the average yield of *jowar* crop usually obtained in these areas of the Bombay-Deccan is usually less than half a ton of total dry matter per acre, indicates that out of the average rainfall of about 26 in. the available quantity of water from the rainfall is not more than 2 in. which is necessary for transpiration for a crop of half a ton per acre. The reasons for the unavailability of rain water in the required quantity are known to be due to dissipation of rain water by surface run off as shown by Kanitkar, *et al.*[1941], and by evaporation and drainage.

Weekly rate of transpiration

Having shown the total water requirement of the *jowar* plant during its whole life-history, it would be interesting to indicate how the intake and outgo of water takes place from week to week. This would be seen by examining the weekly data of water requirement from the seedling stage to maturity. The data for the season of 1940-41 in which the highest dry matter per plant was produced are given in Table IV.

TABLE IV

Weekly transpiration, leaf area, total number of leaves produced and height of the jowar *plant M-47-3 in 1940-41*

(Average of five replications)

Week from sowing	Date of observation	Transpiration in oz.	Leaf area in sq. cm.	Total No. of leave	Height in cm.	Stage of growth
5th	4-11-40	5·6 ±1·15	233·8 ±33·67	9·0 ±0·31	11·6 ±0·48	
6th	11-11-40	18·6 ±2·25	433·4 ±45·9	10·8 ±0·37	13·0 ±0·61	
7th	18-11-40	26·6 ±3·95	723·7 ±112·7	12·0 ±0·63	19·0 ±1·45	
8th	25-11-40	23·4 ±3·74	924·0 ±152·3	13·2 ±0·58	29·0 ±2·17	
9th	2-12-40	45·0 ±5·57	1247·5 ±160·3	16·4 ±0·40	51·6 ±3·72	
10th	9-12-40	52·4 ±5·38	1444·6 ±144·1	16·4 ±0·60	67·2 ±4·94	10-12-40 appearance of flag leaf
11th	16-12-40	56·0 ±4·33	1355·4 ±186·2	16·4 ±0·60	110·0 ±5·54	17-12-40 emergence of ear-head
12th	23-12-40	60·4 ±3·29	1086·8 ±139·3	16·4 ±0·60	115·8 ±6·67	
13th	30-12-40	53·2 ±2·61	829·3 ±112·4	16·4 ±0·60	118·2 ±6·72	
14th	6-1-41	35·2 ±2·09	917·5 ±94·3	16·4 ±0·60	118·2 ±6·72	
15th	13-1-41	27·2 ±2·09	792·3 ±94·3	16·4 ±0·60	118·2 ±6·72	
16th	20-1-41	24·0 ±1·91	660·0 ±98·7	16·4 ±0·60	118·2 ±6·72	
17th	27-1-41	15·2 ±1·62	252·3 ±49·0	16·4 ±0·60	118·2 ±6·72	

(NOTE—Watered on 28 Nov., 11 Dec. and 25 Dec. 1940).

It will be seen that the increase in transpiration was steady till the eighth week. In the ninth week, however, the transpiration suddenly increased to 45 oz. This rise synchronized with a sudden increase in the height of the plant, in the number of leaves and in their area. The greatest increase in height took place in the eleventh week when the emergence of inflorescence took place. The transpiration continued to increase till the twelfth week after which it began to decline. The decrease in transpiration continued steadily till the plant reached its maturity.

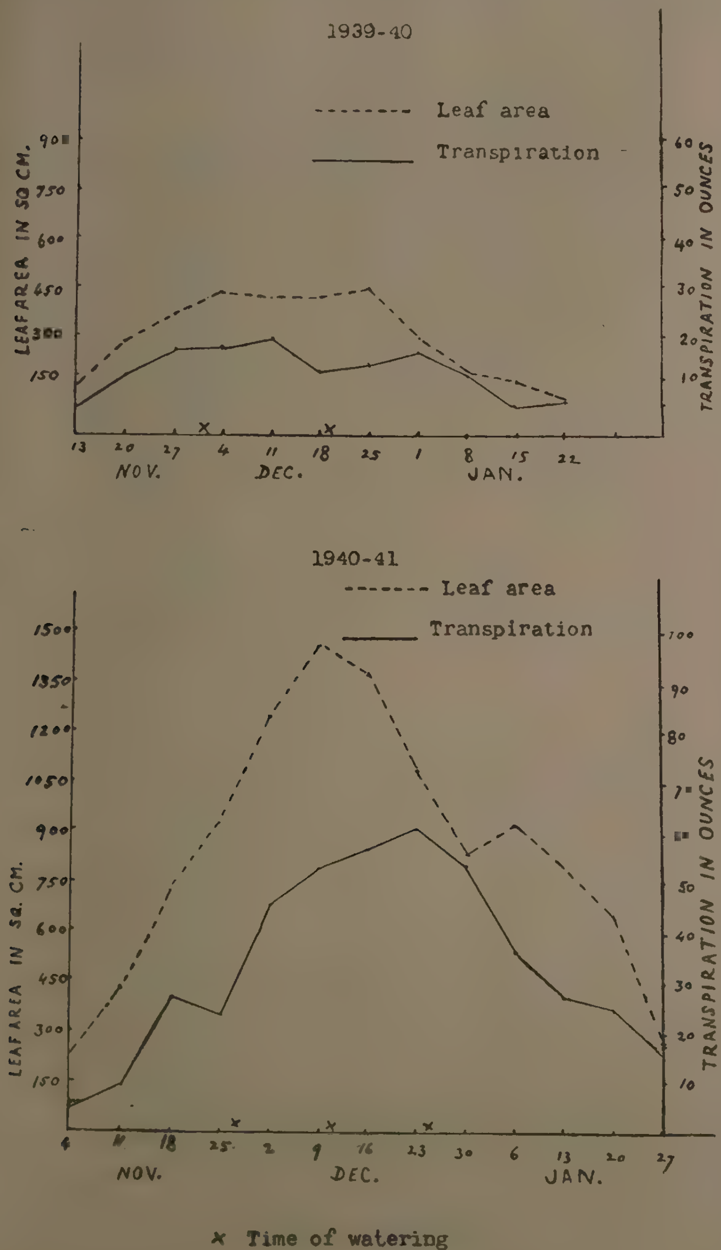

Fig. 1 Relation between transpiration and leaf area in *jowar*

The most important and the critical period in the life of the plant from the point of view of its water requirement seems to be the period from the ninth to thirteenth week when the plant had put forth the maximum number of leaves, and the maximum area for transpiration. During this very period, the inflorescence emerged and the important growth processes of fertilization and grain formation making maximum demand on water took place. This critical period may vary in its time of occurrence and duration in different years due to variation in environmental factors.

Transpiration in relation to leaf area

As stated before, leaf areas of *jowar* plants (Variety M-47-3) in all replicates were computed by the method followed by Patel and Patel [1928] during the years 1934-35 to 1936-37 and by the method of Montgomery [1911] during the remaining four years, i.e. 1937-38 to 1940-41. These measurements were commenced early in November when the plants were just five or six weeks old and continued every week till the time of maturity of the plant. The average results of areas in square centimeters per plant along with the corresponding rates of transpiration in ounces are given in Table IV for 1940-41.

The graphs in Fig. 1 represent leaf areas and transpiration for the years 1939-40 and 1940-41. The results show that the increase in leaf area was soon followed by increase in transpiration. The deviation in a few cases, it will be seen, was due to factors like water addition, greater internal activity of the plant at the stage of flag-leaf emergence or of earhead emergence.

Coefficients of correlation between the leaf area and the transpiration worked out for the seven years give very high values for '*r*'. These can be seen in Table V.

TABLE V

Coefficient of correlation between leaf area and transpiration of the jowar *plant*

Year	No. of observations (pairs)	Value of '*r*'	Whether significant for 5 per cent level
1934-35 . .	14	0·9246	Yes
1935-36 . .	12	0·6826	Yes
1936-37 . .	14	0·9243	Yes
1937-38 . .	15	0·8624	Yes
1938-39 . .	13	0·9067	Yes
1939-40 . .	11	0·7954	Yes
1940-41 . .	13	0·8509	Yes

NOTE—With the exception of 1935-36, the value of the correlation coefficient in all years was significant even to 1 per cent level of probability

Diurnal variation in transpiration

In the conduct of transpiration measurements, when the daily losses increased to several ounces it was considered desirable to get more detailed information regarding the rates of transpiration during different periods of the day. Observations were started on a vigorously growing plant from 3 December 1937 and continued for three weeks. The first weighing was done at sunrise and the second only 1½ hours after sunrise. Further weighings were done every three hours till 5-30 P.M. The last weighing was done at sunset. The data indicating comparative losses during different periods of the day and the losses during the night are given in Table VI.

It will be seen that during the day transpiration increased gradually from sunrise to 11-30 A.M. and after remaining constant till 2-30 P.M. declined till sunset. During the night there was little transpiration, though the evaporation of water from free-water surface continued.

According to Lotfield as quoted by Barton-Wright [1933], the stomata in cereals are closed during the night and are open during the day. The restriction of transpiration in *jowar* to the day time appears, therefore, to be due to the closure of stomatal aperture during the night hours. Leather [1910] studied the diurnal variation in transpiration of a number of crops and found that it was considerably reduced at night. His results obtained for two days showed that in *jowar* transpiration occurred to the extent of about 20 per cent of the total, during the night time of 14 hours.

TABLE VI

Diurnal variation in transpiration as the total of 22 days

(From 3 to 25 December 1937)

Period	7 P.M. to 7 A.M.	7 A.M. to 8-30 A.M.	8-30 A.M. to 11-30 A.M.	11-30 A.M. to 2-30 P.M.	2-30 P.M. to 5-30 P.M.	5-30 P.M. to 7-00 P.M.	Total for 12 hours during the day
Transpiration in ounces	*Nil*	6·0	43·0	43·0	31·0	1·0	124
Transpiration as percentage of total .	*Nil*	4·8	34·7	34·7	25·0	0·5	100

Recuperation of moisture in the jowar *leaf*

As the plant advances, the rate of transpiration by day time increases and as a result it presents a comatose and flaccid appearance in the afternoon. It, however, regains its turgescence during the night due to cessation of transpiration and continued absorption of water from the soil. The excessive transpiration of water through the *jowar* reaf during the day and the extent to which it is lecouped during the night hours has been studied in some detail. Determinations of leaf moisture made on 40 plants by the Ganong punch method of sampling throw light on the variations of leaf moisture during the day and also the extent to which these occur during the important stages of plant growth. The results of these determinations are given in Table VII. The second, third and fourth leaves from the top were used for these determinations.

It will be seen from the figures that in general the moisture content of the leaf was the highest just before sunrise and then began to decrease as the day advanced. The maximum reduction appeared between 12 noon and 4 P.M., a period corresponding to high rate of transpiration which exceeded that of absorption of moisture from the soil. As the process of transpiration slowed down and ceased by sunset, the moisture content of the leaf began to increase. Thus at 8 P.M. it was more than what it was at 4 P.M.

Miller [1917] working with the same method of leaf sampling on the leaves of corn and sorghums

TABLE VII

Variations in the moisture content of jowar *leaves*

(Expressed as per cent on green matter)

Date	Before sunrise	8 A. M.	12 Noon	4 P. M.	8 P.M.	Stage of growth
8 Dec. 1936	92·42	91·31	91·88	89·10	92·30	Buldging
16 ,,	72·35	73·77	69·72	68·72	70·18	Flag-leaf out
23 ,,	70·53	70·50	57·38	47·66	62·47	Ear-head out
30 ,,	69·90	73·99	56·83	60·72	66·74	Fertilization
6 Jan. 1937	69·36	69·79	52·90	61·25	67·66	Milk stage
13 ,,	63·77	60·45	46·16	44·09	57·42	Dough stage
Average .	73·38	73·30	62·49	61·85	69·46	

eached more or less the same conclusions. He ound that in sorghums, viz. Blackhull kafir and Dwarf milo, the minimum percentage of water in he leaves occurred in most cases between 1 and 3 P.M. while the maximum percentage was reached n the majority of cases at 5 A.M.

Experiment II. Requirement of different varieties

For the purpose of this study, two varieties of *jowar* belonging to two distinct groups and believed by the cultivators to differ in their water requirement were chosen. One of them M-47-3, locally known as *Maldandi*, has a loose type of ear-head. This is supposed to consume less water than the compact type. The second variety employed was B-D-34 locally known as *Dagdi* an has a compact type of ear-head. This is considered more suitable under favourable moisture conditions. In addition, one more variety belonging to the loose ear-head type called *Tambdi jogdi*—a red-grained type of *jowar*—which is believed to be most economic in the use of water and is grown generally on *mal* or eroded lands, was used for this experiment. The selfed seeds of these varieties were brought every year from the *Jowar* Breeding Station, Mohol.

The transpiration coefficients of M-47-3 and B-D-34 were determined successively for three years and of *Tambdi jogdi* for two years only. These are given in Table VIII.

TABLE VIII

Coefficient of transpiration of three jowar *varieties*

Year	No. of replications averaged	Weight of shoot *plus* roots in gm.	Coefficient in shoot basis	Coefficient in shoot *plus* root basis
		M-47-3—Loose type		
1934-35 . . .	4	20·39±1·06	482·7±32·2	425·2±38·9
1935-36 . . .	6	18·04±1·52	450·5±26·1	392·3±16·4
1936-37 . . .	6	22·68±1·66	421·3±22·5	375·6±21·3
Average . .	..	20·81	451·4	307·7
		B-D-34—Compact type		
1934-35 . . .	4	20·96±3·59	508·0±65·1	450·0±59·3
1935-36 . . .	6	17·20±1·06	421·4±21·6	372·9±27·4
1936-37 . . .	6	19·23±1·44	418·9±14·8	375·6±17·2
Average . .	..	18·21	456·1	410·0
		Tambdi jogdi—Loose type		
1935-36 . . .	5	20·79±2·62	372·9±20·3	344·4±18·0
1936-37 . . .	6	24·96±1·16	389·5±9·9	349·3±9·6
Average .	..	22·87	381·2	346·8

The results indicate that in all the three years there was no significant difference between the two main groups of *jowar*, viz. the loose M-47-3 and the compact B-D-34, both when the dry matter of the shoot or that of the whole plant including the roots was considered. The third variety, viz. *Tambdi jogdi* showed a significantly lower water requirement only in one year than the other two varieties. This seems to be due to a slightly larger quantity of dry matter produced by the *Tambdi jogdi* as compared with the other two varieties. The total quantity of water transpired by the three varieties varied within the limits of 16·62 to 17·75 lb. per pot, while the dry matter produced varied from 18 to 23 gm. Nearly 25 per cent of this dry matter consisted of the grain weight. It may be noted that the growth of the plants in these experiments under plant-house conditions was fairly normal and comparable with that of plants grown outside in the field (Plate X, fig. 1).

It may be pointed out that the strain of *Tambdi jogdi* was the earliest to complete its life-history. This variety, however, is poor in quality and is not likely to have a market.

An endeavour was therefore made to see whether any early selections from the existing suitable types of *jowar* would exhibit lower water requirement.

Experiment III

(*a*) *Early-maturing selections*. Such a selection was made from *Maldandi* type of *jowar* by selfing an early-growing plant on the farm during the season of 1936-37, which was a year of drought with only 60 per cent of the normal rainfall. The seeds of the selfed plant were used for determining the transpiration coefficients in the following year. The experiment was carried out in six replications. Suitable controls of the variety M-47-3 were also provided. The performance of this early selection was promising in point of earliness, the total quantity of water used and transpiration coefficient on the shoot basis, even though the dry matter was the same as that of the control. The data in this connection are produced in Table IX.

The selfed seed of the second generation was again tried during the season of 1938-39. But this time, the original superiority manifested in the first generation was not to be observed. The results of the two years' experiments to determine the water economy of the early maturing selection showed that the early character of the plant observed in the first year was reduced to only four days at the flag-leaf emergence and to seven days at the start of flowering in the following year and the water economy manifested in the first year could not be corroborated in the second year.

TABLE IX

Comparative performance of an early selection of jowar *during first generation and of the control M-47-3—1937-38*

(Average of 6 replications)

General character	Detailed character	Early selection	Control M-47-3	Mean difference	Significant at 5 per cent. level
1. Dry matter in gm.	Shoot . .	15·29 ±0·99	16·89 ±1·59	1·60 ±1·87	Not significant
	Shoot *plus* root	17·38 ±0·81	20·85 ±1·96	3·47 ±2·12	Do.
	Grain . . .	4·99 ±0·68	3·98 ±0·61	1·01 ±0·92	Do.
2. Transpiration co-efficient	Shoot basis .	438·60 ±14·02	516·80 ±23·15	78·20 ±27·01	Significant
	Shoot *plus* root basis	386·50 ±14·36	417·61 ±15·45	31·11 ±21·09	Do.
3. Water used in oz.	Total . .	234·85 ±2·55	302·31 ±22·75	67·46 ±24·14	Do.
4. Earliness in days from sowing	Up to flag leaf emergence	66·00 ±0·20	90·50 ±4·39	36·50 ±4·83	Do.*
	Up to start of flowering	79·10 ±0·22	98·80 ±4·21	19·50 ±4·74	Do.*

* At 1 per cent level

Another selection of *jowar* was also tried during the season of 1938-39. But the transpiration coefficient of this selection failed to show any significant difference with that of the control.

(*b*) *Plants raised from vernalized seeds.* As the treatment known as vernalization is claimed to induce earliness in a plant, some *jowar* seeds soaked in water were vernalized by subjecting them to low temperature between 4°C. to 10°C. for a period of five weeks. The seeds thus vernalized were employed to ascertain whether the plants grown from them could show low water requirement. The data of this experiment are presented in Table X. They show that the plants grown from vernalized seed failed to show any efficiency in their water consumption. Similarly, neither earliness nor high yields were obtained.

TABLE X

Coefficient of transpiration of jowar *plants raised from vernalized seeds and of the control, variety M-47-3*

(Average of six replications)

	Plants from vernalized seed	Control M-47-3	Mean difference	Significance at 5 per cent level
Transpiration co-efficient on shoot basis	670·70 ±66·13	515·00 ±29·28	155·70 ±72·37	Not significant
Transpiration co-efficient on shoot *plus* root basis	596·70 ±46·10	470·93 ±27·90	125·77 ±53·88	Significant
Grain weight in gm.	1·10 ±0·28	4·77 ±0·48	3·67 ±0·55	Significant
Life period in days	144·8 ±2·5	137·5 ±3·4	7·3 ±4·1	Not significant

Experiment IV. Effect of manures

(*a*) *Farmyard manure.* Experiments were carried out during the three years from 1936-37 to 1938-39 to study the effect of the application of farmyard manure on the water requirement of the *jowar* variety M-47-3. The manure was added to supply 60 lb. of nitrogen per acre and water was added when necessary. The results obtained for two years out of three indicate that the addition of farmyard manure to the soil increased significantly the efficiency of the plants and reduced appreciably its transpiration coefficient. The results of this experiment for the three years are given in Table XI.

TABLE XI

Effect of the application of F. Y. M. and complete fertilizer on the transpiration coefficient of jowar *M-47-3*

(Average of six replications)

Year	Days from sowing			Dry matter of the whole plant in gm.	Transpiration coefficient	
	For flag leaf emergence	For earhead emergence	For grain maturity		Shoot basis	Shoot *plus* root basis
			Unmanured control plants			
1936-37	67·3 ±2·2	77·1 ±2·1	123·1 ±2·6	22·67 ±1·66	421·30 ±22·51	375·60 ±21·29
1937-38‡	91·6 ±4·4	100·0 ±3·9	140·5 ±3·2	20·85 ±1·96	516·80 ±23 15	417·60 ±14·36
1938-39	90·0 ±3·1	99·0 ±2·9	137·5 ±3·3	19·96 ±1·46	515·00 ±29·28	470·93 ±27·90
Average	82·9	92·0	133·7	21·16	484·36	421·37
			Plants manured with F. Y. M.			
1936-37	52·1 ±0·5	64·5 ±0·5	106·2 ±0·5	40·77 ±2·09	308·10 ±8·19	267·10* ±6·95
1937-38‡	87·3 ±3·9	96·0 ±2·4	136·1 ±3·2	18·09 ±1·06	582·20 ±35·60	466·10 ±23·73
1938-39	72·3 ±2·3	80·6 ±1·1	116·6 ±1·2	27·34 ±1·15	416·70 ±22·03	352·40 ±12·46
Average	70·5	80·3	119·6	28·73	435·66	362·06
			Plants manured with complete fertilizer			
1936-37	61·2 ±2·3	73·0 ±2·6	109·7 ±1·3	25·98 ±1·76	315·50 ±5·99	291·40* ±5·05
1937-38‡	86·8 ±4·3	95·6 ±3·8	132·2 ±1·0	24·60 ±0·90	448·50 ±29·36	361·30† ±11·61
1938-39	89·0 ±4·0	94·3 ±3·6	128·5 ±2·8	19·55 ±2·77	495·10 ±30·96	454·70 ±22·03
Average	79·0	87·6	123·4	23·37	419·70	369·13

* Four replications

† Five replications

‡ In 1937-38 there was no response to farmyard manure

In the year 1937-38, there was no response by the plant to farmyard manuring as judged by its dry matter and therefore the beneficial effect of the manure on the reduction of the transpiration coefficient was not noticeable. The coefficient was significantly low even to 1 per cent level of significance in 1936-37 and 1938-39 on the whole plant basis. The average value of the coefficient of the manured plants for two years, viz. 1936-37 and 1938-39, was 310 on the whole plant basis as against 423 under the unmanured conditions. The net increase in dry matter by manuring was as much as 60 per cent, while the total increase in the quantity of water required was only 16 per cent.

(*b*) *Complete fertilizer.* Complete fertilizer was applied to supply 60 lb. of nitrogen, 72 lb. of potash and 220 lb. of phosphoric acid per acre. The actual substances used to provide the above ingredients were ammonium sulphate, potassium sulphate and calcium phosphate. The quantity of the mixture added to each pot containing 70 lb. of dry soil, amounted to only 12·5 gm. As the quantity of soil per pot was limited, the quantities of fertilizers were added at a somewhat higher rate. Water was added in this experiment when necessary.

The results of the transpiration coefficients of *jowar* obtained successively for three years are given in Table XI. They show that the coefficients of the manured plants were significantly lower even to a level of 1 per cent in 1936-37 and to 5 per cent level in 1937-38 on the whole plant basis. In the year 1938-39, the coefficient was also lower but the difference was not statistically significant.

On the basis of the average results of the three years it was found that for almost the same quantity of water utilized both by the manured and unmanured plants, the transpiration coefficient of the former was considerably lower than that of the latter. The efficiency of the plants in water economy under application of complete fertilizer was of the same order as that of plants treated with farmyard manure.

Another beneficial effect arising from the manurial treatments was the shortening of the life period of the plant. When the plants were manured with farmyard manure, the stages of flag-leaf emergence, ear-head emergence and maturity were all attained two weeks earlier than in the case of the untreated controls, specially in the two years, viz. 1936-37 and 1938-39, where the effect of the manure was reflected on dry matter production. In the case of the complete fertilizer treatment, a similar effect was observed but it was less marked. This earliness was mainly due to a more vigorous and earlier start received by the manured plants, as will be evident from the figures of growth record taken one month after sowing and given in Table XII.

TABLE XII

Average performance of the jowar *plant under manurial conditions*

(Weekly transpiration in oz.)

Dates	Treatment	Transpiration	Leaf area in sq. cm.	No. of leaves present	Total No. of leaves produced	Height in cm.
3 Nov. 36	Control	5·0	115·7	5·5	8·6	7·2
	F. Y. M.	23·5	386·2	7·5	10·5	11·5
	Complete fertilizer	6·3	147·1	5·7	8·7	7·8
1 Nov. 37	Control	5·5	123·8	4·7	7·7	7·6
	F. Y. M.	5·9	171·8	4·8	7·8	9·0
	Complete fertilizer	6·5	163·8	5·2	8·0	9·1
7 Nov. 38	Control	9·0	83·7	4·3	6·8	7·6
	F. Y. M.	9·9	200·8	5·6	8·6	9·3
	Complete fertilizer	8·2	107·2	4·5	6·8	8·7

This earliness secured by manuring has great economic importance in the scarcity areas where soil moisture operates as a limiting factor for crop growth. It may be pointed out that the two processes, viz. transpiration and evaporation, go on simultaneously especially under field conditions. If more water is used in transpiration due to rapid development of the plant under manured conditions, there will be comparatively less water available for evaporation. The quicker growth of plants with manures thus utilizes more water for transpiration and indirectly results in lowering the loss of moisture by evaporation.

This rapid utilization of soil moisture by the manured plants could be seen from the data of water transpired at early and late stages of plant growth. In the year 1936-37, nearly 55 per cent of the total quantity of water required by the plants for their complete life-cycle was utilized before the end of November, that is within eight weeks from sowing, whereas the corresponding plants without manure used only 31 per cent of their total water requirement for their whole life-cycle. In the year 1938-39, nearly 30 per cent of the total quantity of water was utilized by the manured plants till the end of November as against 14 per cent by the unmanured plants. It may be pointed out that the quantity of water transpired till the end of November was mostly lost in the month of November alone, as transpiration during the first month, i.e. October, was almost negligible.

In the case of the complete ferilizer treatment, the effect was less marked. In 1936-37, the amount of water used till the end of November was only 38 per cent of the total quantity of water transpired, as against 31 per cent used by control plants. In the following two years there was not much difference between the manured and control plants.

The effect of the application of manure on root production is shown in Table XIII. Root production was not much affected by the use of complete fertilizer. But the effect of farmyard manure was very much pronounced. Plants treated with farmyard manure produced over 40 per cent more roots than the unmanured and developed a better root system, as will be seen from the figures of dry matter of the roots. The shoot to root ratio was very low in the plants treated with farmyard manure.

TABLE XIII

Effect of the application of farmyard manure and complete fertilizer on root production

Year	Replications averaged	No. of main roots from nodes	Dry matter of roots in gm.	Dry matter of shoot in gm.	Ratio of shoot / root
Plants manured with F. Y. M.					
1936-37	4	37·0	4·84	35·45	6·60
1938-39	6	23·0	4·04	23·30	6·35
Average	...	30·0	4·44	29·37	6·47
Plants manured with complete fertilizer					
1936-37	4	23·7	1·96	24·02	12·20
1938-39	6	22·5	1·46	18·09	15·13
Average	...	21·6	1·71	21·30	13·66
Control plants without manure					
1936-37	6	26·6	2·48	20·18	8·40
1938-39	6	16·3	1·74	18·25	11·40
Average	...	21·4	2·11	19·21	9·90

(c) *Sunn green manure.* The addition of sunn green manure (*Crotalaria juncea*) to the soil in the years 1937-38 and 1938-39 at the rate of 60 lb. of nitrogen to an acre failed to effect any reduction in the transpiration coefficient of the *jowar* plant. In both the years, there was no response by the plant to the added manure and the coefficients were almost identical with those of control plants.

Experiment V. Plants subjected to drought

In the conduct of the majority of the experiments so far described, water was added once or twice during the life-cycle of the *jowar* plant when the plants showed symptoms of incipient wilting. It was decided to delay this addition in one set of experiments so as to allow the plants to experience a short period of drought, before the buldging stage. During the season of 1937-38, duplicate pots in two sets, viz. manured and unmanured, were subjected to such a period of drought for two weeks after the first symptoms of incipient wilting had appeared, before water was added. The effects of this treatment are shown in Table XIV. The moisture content of the soil at the stage of incipient wilting when the plants showed a distinct drop in transpiration was about 30 per cent which was made up to 38 per cent after two weeks.

TABLE XIV

Water requirement of the jowar *plant (M-47-3) subjected to a drought period of 15 days at the buldging stage, 1937-38*

Stage of growth	Control plant without drought	Plants subjected to drought	
		Unmanured	Manured with complete fertilizer
1. Days of emergence of flag-leaf	67·0±2·20	83·0±2·0	83·0±1·0
2. Days for emergence of ear-head	77·1±2·06	92·0±0·0	93·5±1·5
3. Days for maturity of grain	123·1±2·56	131·0±1·0	130·5±1·5
4. Grain in gm.	3·98±0·06	8·64±0·87	9·15±0·83
5. Total dry matter in gm.	20·85±1·96	21·64±1·38	25·20±0·84
6. Transpiration in oz.	302·3±20·17	285·10±12·50	274·60±10·00
7. Transpiration coefficient—			
(*a*) Shoot basis	516·8±23·15	419·20±12·00	364·2±1·85
(*b*) Shoot *plus* root basis	417·6±14·36	369·10±12·43	308·9±0·90

The results show that the number of days required from sowing for the completion of different stages of growth except the final stage increased by the same period for which the plants were exposed to drought. Under normal conditions, viz. with just sufficient supply of soil moisture, the number of days required for the emergence of flag-leaf were 67. With a drought of one fortnight, this number increased to 83 days. For the emergence of ear-head in the control plants, the days required were 77 as against 92 in the drought experienced plants. Similarly, the control plants matured in 123 days while those subjected to drought required 131 days for complete maturity.

In spite of the delayed maturity, the quantity of water used by the unmanured and manured plants subjected to drought was respectively 285 and 274 oz. as against 302 oz. used by the control plants without drought. The actual grain produced per plant exposed to drought was distinctly higher. This finding can be useful under irrigated conditions where some delay in the application of water at the early stage may be beneficial.

Experiment VI Influence of soil type

In the season of 1934-35, transpiration coefficient of two strains of *jowar* was determined on two types of soil from Sholapur, viz. the medium deep and the light shallow. The physical and chemical characters of the medium deep soil of Sholapur or the standard type have already been described. The light shallow soil of Sholapur is highly eroded soil with only 5-6 in. depth and with about 32 per cent clay content. It is extremely porous. Chemically it is poor in nitrogen and the phosphoric acid is not only low but is also in an unavailable form. The same quantity of soil, viz. 80 lb. was used in each pot. The results are given in Table XV.

TABLE XV

Transpiration coefficient of jowar *in different soils*

Year	Soil type	Variety	Life period in weeks	Total dry matter in gm.	Transpiration coefficient	
					Shoot basis	Shoot *plus* root basis
1934-35	Medium deep Sholapur	M-47-3	21·0	20·39	482·7 ±33·23	425·15 ±38·89
	Ditto	B-D-34	22·3	20·96	508·0 ±65·05	450·15 ±59·28
	Light shallow Sholapur	M-47-3	21·0	26·55	355·8 ±28·81	307·20 ±24·05
	Ditto	B-D-34	21·0	26·53	332·5 ±15·29	302·05 ±11·41
1939-40	Medium deep Sholapur	M-47-3	16·5	14·32	300·4 ±17·74	282·0 ±17·14
	Deep black Bijapur	Do.	17·1	9·74	312·1 ±12·12	288·1 ±13·27
	Limy Bijapur	Do.	17·5	12·43	399·0 ±44·47	329·3 ±26·08
1940-41	Medium deep Sholapur	Do.	17·0	42·14	344·7 ±17·6	307·6 ±15·3
	Deep black Bijapur	Do.	17·0	16·20	492·4 ±33·6	453·8 ±33·5
	Limy Bijapur	Do.	16·3	29·86	387·8 ±15·1	340·5 ±10·5

The light shallow soil which is porous, allowed better root and shoot growth and finally lowered the transpiration coefficient in both the varities. The medium deep soil is very clayey and the plant growth was slow. The total dry matter produced was less than that in the light shallow soil.

Two soils from Bijapur were used along with the standard soil from Sholapur in two seasons of 1939-40 and 1940-41. The two Bijapur soils, viz. the deep and the limy have great depths and contain 56 and 46 per cent clay respectively. The limy soil is characterized by heavy admixture of lime nodules or *kankar*. Chemically both are low in nitrogen and phosphoric acid. The deep soil becomes impervious to rain water after a sharp shower of rain, while the limy soil allows easy penetration of rain water. The results are given in Table XV.

The results indicate that the transpiration coefficients may be influenced by soil types in some seasons. The two Bijapur soils gave higher transpiration coefficients than the Sholapur standard soil in the year 1940-41, the difference being significantly higher in deep soil but only slightly higher in the limy. In 1939-40, there was no significant difference and the plants in all the three soils had not grown to normal size and weight.

Experiment VII. Transpiration and evapo-transpiration coefficient under field conditions

To corroborate the results of transpiration experiments carried out in pots under controlled conditions in the plant-house, plot experiments were conducted in the field at Sholapur in two seasons, viz. 1940-41 and 1941-42. During these years, good crops could be raised on plots in which water from rainfall only was absorbed and conserved. A square plot measuring 1/20th of an acre with uniform soil depth of 18 in. was divided into quadrants. The soil type was the medium deep or the standard soil described before. The four quadrants were separated and protected on all sides by plain galvanized iron sheets 18 in. wide, driven 9 in. deep vertically and fixed by stout iron stakes. Two of these quadrants were kept fallow as controls. The other two were sown with *Maldandi jowar* with loose ear-head by dibbling the seed one foot each way.

Soil moisture tests were taken layer by layer at the commencement of the experiment and then again once every month. At each test, about 40 plants from two rows from the duplicate plots were removed carefully, washed free of soil, dried in the oven and weighed. Soil samples from the spots from which plants were removed were taken and the moisture content determined. Soil samples from the fallow plots were also simultaneously taken and examined for moisture content. The former set of samples gave losses due to transpiration and evaporation and the latter losses due only to evaporation. Water requirement at different stages of the plant growth was thus determined from these data. Results at the maturity stage only are given in Table XVI.

The results of plot experiments show that the transpiration coefficients obtained under field conditions at the final stage were 180 and 241 for the years 1940-41 and 1941-42 respectively, which were lower than those found from plants grown in pots under plant-house conditions. In the plot experiments, the evaporation from uncropped or fallow plots was uncontrolled and hence gave higher values for evaporation. The lower transpiration coefficient under field conditions was thus due to the deduction of the exaggerated evaporation from the total combined loss by transpiration and evaporation from the cropped plots. The total soil mass per plant was also higher than in pots and this might also reduce the transpiration ratio to some extent. Hence the combined evapo-transpiration coefficients of 1031 and 972

TABLE XVI

Evapo-transpiration and transpiration coefficient of jowar *grown in small plots in the field*

(Average of four replications)

Year	Sampling area in sq. ft.	Cropped plot			Uncropped plot			Water transpired in lb. (A—B)	Water lost by evapo-transpiration in lb.	Dry matter of shoot in lb.	Transpiration co-efficient	Evapo-transpiration coefficient
		Initial soil moisture in lb.	Soil moisture at harvest in lb.	Total loss of moisture in lb. (A)	Initial soil moisture in lb.	Soil moisture at harvest in lb.	Total loss of moisture in lb. (B)					
1940-41	20	1107·32	613·39	493·93	1141·71	806·30	335·41	158·51	907·35*	0·8802	180·09	1030·8
1941-42	18	970·75	639·09	331·66	969·60	753·22	216·38	115·28	464·78†	0·4784	240·96	971·7

* Including 3·97 in. of rainfall during the crop period from 28 Sept. 1940 to 20 Feb. 1941. having 15 rainy days with a variation of rainfall from 0·02 to 1·47 in.

† Including 1·42 in. of rainfall during the crop period from 1 Oct. 1941 to 30 Jan. 1942. having four rainy days with a variation of rainfall from 0·07 to 0·63 in.

indicate more correctly the quantities of water lost from the soil by simultaneous transpiration and evaporation.

On the basis of the average value of the evapo-transpiration coefficients for the two years, the amount of water required by the *jowar* crop for the simultaneous processes of transpiration and evaporation can be estimated. The average yield of the *jowar* crop per acre for the two years on a soil of medium fertility like the medium deep soil of Sholapur was 975 lb. while the average value of the evapo-transpiration coefficients was 1001. From these figures it is estimated that the *jowar* crop during the two years must have required water equal to 4·2 in. of rainfall. Actually, the quantity of water transpired was much less, that is equal to 1·8 in. of rainfall, calculated from the average value of transpiration coefficients determined for a period of seven years. Even this quantity does not become available to the crop, owing to large losses of soil moisture by direct evaporation.

It may be pointed out that a large quantity of rain water remains in the soil unutilized being held by soil colloids. This may amount to 5 to 6 in., assuming the soil depth of about 18 in. The loss of rain water due to evaporation during the crop growth is unavoidable and hence water available for the use of plant is the balance left after evaporation and after allowing for the quantity of water held by the soil as unavailable. The yield therefore fluctuates according to this available balance of rain water for the use of the crop. If less than 15 in. of water be available for the crop from sowing to flowering, it only results in reducing the yield of the *jowar* crop under the climatic conditions of the scarcity tracts of the Bombay-Deccan.

Summary and conclusions

(1) Series of experiments on water requirement of *rabi jowar* or sorghum were carried out at the Sholapur Dry Farming Research Station for seven years from 1934-35 to 1940-41 in a specially erected plant-house to protect the plants from rain, with suitable potometers of glazed earthenware. Four to six replications were used in all experiments.

(2) The average water requirement of the *jowar* plant (*Maldandi* variety M-47-3 with loose ear-head type) during six years amounted to 18·4 lb. per plant with an average weight of 23·06 gm. The average transpiration coefficient for six years was 424 and varied from 300 to 516 in different years according to climatic or seasonal conditions when calculated on the shoot basis only, the roots being omitted. This indicates that in order to obtain one ton of *jowar* crop in the Sholapur tract, nearly 4·25 in. of rain water is actually utilized by the crop. This may vary from 3 to 5·2 in. in different seasons.

A high correlation between transpiration and leaf area was found to exist in all years. The actual value of 'r' varied from $+0·68$ to $+0·92$ in different years.

Diurnal rates of transpiration recorded for three weeks of intense activity during December 1937 showed that the highest rate of transpiration took place during the period of six hours, viz. 8-30 A.M. to 2-30 P.M. and that the transpiration was restricted only to the sunshine hours from surnrise to sunset.

The moisture in the leaf fluctuated a good deal during 24 hours of the day. It was maximum just before sunrise and decreased steadily as the day advanced. The maximum reduction appeared between 12 noon and 4 P.M., a period corresponding to the high rate of transpiration.

The most important and critical period in the life of the *jowar* plant from the point of view of its water intake was found to extend from the 9th to the 13th week after germination, covering the period of flag-leaf emergence and the ear-head appearance.

(3) Three distinct varieties, viz. M-47-3 and *Tambadi jogdi* belonging to loose ear-head type, and B-D-34 belonging to compact ear-head type were tested. The varieties M-47-3 and B-D-34 showed no significant differences in their water requirements. The red type *Tambadi jogdi* was early to mature and showed somewhat lower water requirement than the other two.

(4) Other strains selected for earliness and *jowar* plants raised from seeds of M-47-3 treated for inducing earliness by vernalization showed no consistent water economy. Early strain showed some economy in the first generation but this was not maintained in the second generation.

(5) Experiments to study the effect of additions of farmyard manure, complete fertilizer and sunn green manure so as to supply 60 lb. of nitrogen per acre were carried out for three years. The results indicated that on the whole there was distinct economy in the use of water by the *jowar* plant by the addition of farmyard manure and complete fertilizer. The transpiration coefficients were significantly lower in two years out of three by farmyard manure and also by fertilizer. Sunn green manuring showed no economy. It was further found that the application of farmyard manure cut short the life period of the plant.

(6) *Jowar* plants grown with necessary supply of water when exposed to partial drought for two weeks prior to buldging gave lower transpiration coefficient than those which were not subjected to any drought, the difference being statistically significant.

(7) *Jowar* plants grown in four different soils gave varying values of transpiration coefficients. Soil which allowed early and quick plant growth

gave a lower transpiration coefficient as was the case in the light shallow soil of Sholapur when compared with the standard medium deep soil from the same station. The two Bijapur soils, viz. the deep black and the limy, gave somewhat higher transpiration coefficients but the differences were not significant.

(8) To corroborate the pot experiments conducted in the plant-house, small plot experiments in the field under natural rainfall conditions were carried out during two years, viz. 1940-41 and 1941-42. The actual values of transpiration coefficients for the two years were 180 and 241. These were distinctly lower than those under pot-house conditions and were due to the fact that the evaporation from the uncropped plots continued uncontrolled whereas it was greatly checked by the covers on the control pots in the plant-house. As the total loss was due to the simultaneous processes of evaporation and transpiration, any increase or decrease in one would affect the other in the opposite direction.

But the evapo-transpiration ratio which is based on the combined loss in both these directions is a more useful figure and indicates the actual loss of soil moisture under field conditions. This ratio for the two years, viz. 1940-41 and 1941-42, was 1031 and 972 respectively.

These results when interpreted in terms of crop yield show that in order to obtain the average yield of about 1,000 lb. of *jowar* crop (grain and straw combined) nearly four to five inches of rain water would be necessary for the two simultaneous processes of evaporation and transpiration.

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APPENDIX

Table I

Meteorological observations recorded at eight hours local time

(Average of five months from October to March)

Year	—	Maximum temperature °F.	Minimum temperature °F.	Mean temperature °F.	Solar radiation °F.	Hours of sunshine	Relative humidity percentage	Wind velocity in miles per hour	Evaporation in m.m. from free water surface	Total rain in inches from October to March	Total rainfall for the whole year in inches
1934-35 .	Average . .	86·8	58·0	72·6	147·5	9·28	60·1	4·29	8·02	2·09	22·58
	Range .	76·0 to 95·0	45·0 to 72·0	63·0 to 83·0	125·0 to 161·0	0·5 to 11·2	27 to 95	1·66 to 12·10	0·50 to 13·07		
1935-36 .	Average . .	86·6	59·7	73·2	147·9	9·06	61·9	4·30	7·67	7·69	28·65
	Range .	81·0 to 94·0	50·0 to 75·0	66·0 to 84·5	132·0 to 162·0	1·2 to 10·9	32 to 95	1·87 to 11·60	0·0 to 12·8		
1936-37 .	Average . .	88·2	60·8	75·5	145·2	8·88	59·8	5·13	8·78	4·50	14·91
	Range .	77·0 to 98·0	40·0 to 76·0	58·5 to 86·0	132·0 to 161·0	0·10 to 10·65	35 to 95	1·16 to 14·40	1·51 to 17·56		
1937-38 .	Average . .	88·2	60·7	74·5	144·1	9·16	53·5	5·34	9·15	7·20	27·87
	Range .	76·0 to 95·0	40·0 to 72·0	60·0 to 81·5	138·0 to 156·0	0·30 to 10·60	21 to 98	2·50 to 11·06	0·0 to 15·30		
1938-39 .	Average . .	87·8	59·4	73·6	143·8	9·36	51·2	5·05	7·89	1·07	37·30
	Range .	75·0 to 96·0	46·0 to 71·0	65·0 to 82·5	109·0 to 158·0	0·0 to 10·80	23 to 95	2·50 to 11·34	1·39 to 14·20		
1939-40 .	Average . .	88·6	59·0	73·8	144·7	9·18	53·6	5·25	8·80	1·18	13·86
	Range .	80·0 to 97·5	46·0 to 76·0	64·0 to 85·5	137·0 to 160·0	0·0 to 10·7	26 to 85	2·29 to 11·04	1·55 to 15·40		
1940-41 .	Average . .	89·1	61·5	75·3	143·8	9·02	56·3	4·83	8·04	3·97	27·35
	Range .	76·0 to 98·5	46·0 to 72·0	63·0 to 83·0	115·0 to 161·0	0·4 to 11·0	23 to 95	1·75 to 9·53	1·35 to 19·82		

STUDIES OF INDIAN RED SOILS

VII. INFLUENCE OF RAINFALL AND ALTITUDE ABOVE SEA-LEVEL ON THE CHEMICAL COMPOSITION OF CLAY FRACTIONS OF SOIL TYPES

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ROBINSON and Holmes [1924] examined the relationships between the mean annual rainfall, temperature and the chemical compositions of 45 clays, as exemplified by the molecular ratios $\frac{SiO_2}{Al_2O_3+Fe_2O_3}$ and $\frac{CaO+Na_2O}{Al_2O_3+Fe_2O_3}$ soil samples from 30 centres in the United States and have found an inverse relationship between these ratios and the rainfall, but they could trace none with the temperature. Crowther [1931] has separated the effects on soil formation of rainfall and temperature by a statistical examination of the data of Robinson and Holmes and has shown that the existence of a high positive correlation between annual rainfall and mean annual temperature in the agricultural areas of the United States accounts for the failure of Robinson and Holmes to recognize the influence of temperature on clay composition. Crowther has shown that the ratio of silica to alumina in the clay fraction is correlated negatively with rainfall and positively with temperature. In the present paper the mean annual rainfall and altitude data and the $\frac{SiO_2}{Al_2O_3}$ ratio of the clay fraction of lateritic soil samples of surface layers from 22 different localities of India have been considered. The relative importance of the effects of the rainfall and altitude on the composition of the clay fractions was estimated by evaluating the standard errors of the individual regression coefficients and applying student's *t*-test to the 22 samples. Preliminary examination of the temperature data indicated that temperature has no significant correlation with the $\frac{SiO_2}{Al_2O_3}$ ratio of the clay fraction nor with the rainfall of the locality.

EXPERIMENTS AND RESULTS

The clay fractions were analysed by following the procedure of A. O. A. C. [1938].

Table I gives the data of annual rainfall in inches, altitude above sea-level in feet and mean temperature of the localities from where the soil samples were collected.* The character of the parent material is also shown in the same table. Table II compiles the laboratory soil numbers, depths and the $\frac{SiO_2}{Al_2O_3}$ ratios of the clay fractions of the soil samples.

* The data of annual rainfall and those of the temperatures of the localities representing the mean values, usually of ten years and taken from the nearest recording stations, were calculated from values kindly supplied by the Meteorological Department of the Government of India. The data of altitude above sea-level representing the mean altitude of the locality were kindly supplied by the Department of the Survey of India.

TABLE I

Annual rainfall, altitude and temperature data of the localities from where the soil samples were collected and the character of the parent material

Locality	Laboratory No.	Annual rainfall (in.)	Altitude above sea-level (ft.)	Mean temperature in degrees	Character of parent materials
Dacca Farm, Bengal	1p	69·2	26†	72	Old Alluvium
Suri, Birbhum, Bengal	4p	57·0	219	83	Recent deposit
Bidar, Hyderabad, Deccan	10p	28·0	2202	82	Basalt
Himayetsagar, Hyderabad, Deccan	18p	28·3	1600	80	Granite (Gneiss)
Telankheri, Nagpur, C. P.	23p	55·6	1017	77	Basalt

†Altitude for Narayanganj which is about 10 miles from Dacca, and almost at the same level

TABLE I—*contd.*

Locality	Laboratory No.	Annual rainfall (in.)	Altitude above sea-level (in.)	Mean temperature in degrees	Character of parent materials
Chandkheri Farm, Raipur, C. P.	33p	49·0	1000	79	Supposed to be limestone
Alisagar, Hyderabad, Deccan	42p	40·5	1500	77	Quartz
Kakat, Cannanore, Malabar	45p	124·6	100	80	Granite
Puzathi, Cannanore, Malabar	53p	124·6	100	80	Granite
Nilgiri Hills,‡ Madras Presidency	56p	56·0‡	5000	59‡	Charnokite
Nilgiri Hills,‡ Madras Presidency	59p	56·0‡	7000	59‡	Charnokite
Guntur, Madras Presidency	65p	30·4	200	102	Granite (probably soda lime granite)
Trivandrum, Tranvancore	70p	65·0	200	86	Gneiss
Government Fruit Farm, Cape Comorin	73p	65·0	100-125-150	86	Gneiss
Hathwara, Manbhum, Bihar	81p	46·9	2000	68	Granite and syenite
Putida, Singhbhum, Bihar	87p	45·0	762	68	Dalma trap and Mergui Volcanics
Ratu, Ranchi, Bihar	90p	58·1	2000	74	Unclassified crystalline gneiss, etc.
Baralota, Daltonganj, Bihar	94p	45·2	762	100	Limestone, shales and slates
Tangi, Cuttuck, Orissa	98p	60·7	70	75	Laterite mixed with granites and sandstones
Dhanmandal, Cuttuck, Orissa	101p	64·7	105	75	Laterite mixed with granites and sandstones
Kapileswar, Bhubaneswar, Orissa	103p	67·8	108	80	Gneiss
Jhinkartangi, Khurda Town, Orissa	106p	59·3	75	50	Gneiss

‡ The annual rainfall and the mean temperature of Nilgiri Hills at altitudes 5000 and 7000 above sea-level have been assumed to be the same as those recorded at Ootacumond

TABLE II

Soil No.	Depth	$\frac{SiO_2}{Al_2O_3}$ of the clay fractions
1p	0 in.—6 in.	2·83
4p	0 in.—1 ft.	4·81
10p	0 in.—1 ft. 4 in.	2·07
18p	0 in.—3 in.	2·74
23p	0 in.—2 in.	2·67
33p	0 in.—4 in.	3·70
42p	0 in.—1 ft.	3·01
45p	0 in.—1 ft. 3 in.	1·79
53p	0 in.—1 ft. 8 in.	2·49
56p	0 ft.—1 ft.	2·03
59p	0 in.—1 ft.	1·58
65p	0 in.—1 ft.	4·49
70p	0 in—1 ft. 6 in.	2·05
73p	0 in.—6 in.	2·28
81p	0 in.—1 ft. 6 in.	2·36
87p	0 in.—1 ft.	2·82
90p	0 in.—1 ft.	1·69
94p	0 in.—1 ft. 11 in.	3·05
98p	0 in.—1 ft.	3·78
101p	0 in.—5 in.	2·27
103p	0 in.—2 ft. 11 in.	2·25
106p	0 in.—1 ft.	2·25

The regression equation for clay composition[8] on rainfall and altitude is given in Table III. For the purpose of calculating the standard errors of the individual regression coefficients and applying student's *t*-test, the geological factor was neglected, although it is quite likely that geological factor will have a significant influence on the nature of the soil type which is formed [Crowther, 1931]. Also, preliminary calculations showed that temperature has not got any significant influence on the chemical composition of the clay fraction which may be explained by the fact that at all the temperatures of the soils worked with (Table I), the organic matter will be destroyed and the positive correlation of temperature with the composition of the clay fraction, which may be observed with soils of the temperate climates, will be absent in such cases, which was actually found to be the case.

Five per cent value of t for 19 degrees of freedom = 2·093. Hence both the regression coefficients are significant. It may thus be concluded that, so far as lateritic soils are concerned, both annual rainfall and altitude above sea-level possess significant negative correlations with the $\frac{SiO_2}{Al_2O_3}$ ratio of the clay fraction.

TABLE III

*Regression equation for clay compositions on rainfall and altitude**

	Regression coefficient	
	SE	t
$S = 3\cdot882457 - 0\cdot015153R$ S on R	0·006735	2·25
$-0\cdot000258H$ S on R	0·00009617	2·68

* R = Mean annual rainfall in inches
H = Mean altitude in feet above sea-level
S = Molecular ratio of SiO_2 to Al_2O_3 in the clay fraction
SE = Standard error

The highly significant negative correlation of the $\frac{SiO_2}{Al_2O_3}$ of the clay fraction with the altitude suggests that greater leaching of silica of the clay fraction with increase in the altitude occurs which may take place down the deeper layers of the soils.

SUMMARY

In the present paper the effects of annual rainfall and altitude data on the $\frac{SiO_2}{Al_2O_3}$ ratios of the clay fractions of lateritic soil samples from 22 different localities of India have been estimated by evaluating the standard errors of the individual regression coefficients and applying student's t-test.

It has been concluded, that so far as lateritic soils are concerned, both annual rainfall and altitude above sea-level data possess significant negative correlation with the $\frac{SiO_2}{Al_2O_3}$ ratios of the clay fractions.

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FURTHER STUDIES ON THE DISTRIBUTION AND SEASONAL HISTORY OF COTTON STEM WEEVIL—*PEMPHERULUS AFFINIS* (FST.)—IN SOUTH INDIA

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The Indian Central Cotton Committee initiated a scheme of studies on the incidence, distribution and natural enemies of *Pempherulus affinis* (Fst.) in October 1935 for a period of three years. The results of this investigation were embodied in a paper [Krishna Ayyar, 1942]. Investigations on certain aspects of the problem could not be completed within the allotted period. In order to fill in the lacunae, a supplementary scheme for a period of one year was sanctioned by the Indian Central Cotton Committee from 31 October 1939. The results of this investigation, particularly on the distribution and seasonal history of the pest, are recorded here.

Previous studies

The results of the previous studies may be briefly recapitulated thus. *Pempherulus* is highly destructive in most cotton-growing tracts of the southern part of the province such as Coimbatore, Ramnad, Madura and Tinnevelly and its destructiveness increases with the advance of the season. It occurs in a few other provinces in India such as Bihar and the United Provinces, but not in considerable numbers. Outside India, it is known to be present in Burma and the Philippines only. From available evidence the weevil is supposed to be of indigenous origin. Its association with wild host plants in virgin forests lends support to this view. The seasonal history has been studied to some extent, though its behaviour is somtimes apparently erratic resulting in considerable fluctuations during different periods and seasons, situation and localities. The influence of physical features in this regard was sought to be investigated by a study of its biology under controlled conditions of temperature and humidity. Differential requirements of these factors were observed for each phase of the life of the insect. Besides cotton, the insect is now known to breed definitely in a variety of food-plants, about 14 in number. Parasitism was noted both in cotton fields and in association with other food-plants. A large number of such parasites is absent in cotton fields. The biology and host-parasite relationship of some of these have also been studied.

Distribution

Data on distribution were obtained by brief surveys in some selected districts not previously investigated. Four ecologically distinct tracts were explored. The first of these comprised North Arcot and Salem districts. The next place was Malabar which, though devoid of cotton cultivation, is an important tract for wild food-plants and parasites of the weevil; the southern and central districts comprising Trichy, Tanjore, South Arcot, Chingleput and Chittoor formed another distinct area investigated; finally the southern portion of South Canara, ecologically very different from other regions, was also rapidly surveyed. Since the surveys were rapid and restricted, it was possible only to gather general data on the occurrence or absence of the weevil. These observations, however, shed considerable light on the distribution and habits of the weevil and will serve to supplement what has already been written on the subject. Recent enquiries outside India have added another country namely Siam where *Pempherulus* is reported to occur in considerable numbers.

Some general considerations

In discussing the pest situation it is essential to keep in mind the close relation between incidence and the course and extent of cotton in the tract. Besides, the abundance or absence of the alternate food-plants of the weevil is another important factor. Unquestionably of equal importance are the ecological factors of the tract inclusive of the agricultural and climatic features. It is also probable that the plant associations of a particular situation may exercise some influence on the presence or absence of the pest. It was obviously impossible to collect all such data in a brief survey of a few localities. Separate accounts of each of these regions are given below.

North Arcot. Very little cotton is cultivated here; it is grown in small minute patches occasionally alternating with other crops as paddy, *ragi* or groundnuts. *Pempherulus* does not occur on cotton in any of the places surveyed in the district, although isolated specimens of the weevil were recovered from alternate food-plants like *Hibiscus esculentus*. Its occurrence in the district, however, constitutes a potential menace to cotton crops, especially when the latter develops into extensive mono-cultures.

Salem. Cotton occupies extensive areas and forms an important crop of the district. The best and most fertile soils are reserved for groundnut and Cambodia cotton. The next best soils are set apart for *cumbu*, one of the staple food crops. Soils still inferior are brought under *cholam*, an important fodder crop for cattle. Lastly, soils unsuitable for other purposes are sought to be utilized for Nadam, a perennial drought-resistant variety of cotton. Only stray infestations of cotton by the weevil could be located in many localities. On the other hand, the weevil has been encountered, though in small numbers in alternative food plants, particularly of the species *Hibiscus esculentus*. The incidence in cotton may at present be regarded as almost negligible in Salem taluk. In Tiruchengode and Namakkal taluks, on the other hand, the weevil has to be reckoned as a serious pest especially so in the perennial variety Nadam. Heavy multiple infestations accompanied by overlapping crowds of large-sized galls form a normal feature in the second year of its standing. Cambodia cottons raised in their vicinity showed a heavier incidence than those at a distance.

Malabar. Ecologically, the localities investigated were more or less uniform in respect of rainfall and climatic conditions but yet these varied somewhat in vegetation and cultural practices. These latter are greatly influenced by the monsoons and the area as a whole may be described as very humid. The region lying between the ghats on one side and the sea coast on the other is highly hilly and undulating interspersed with extensive forests. Naturally the variations in altitude were reflected in the divergence in the types of vegetations and agricultural practices. The district as a whole is devoid of any cotton cultivation but presents vast stretches of the wild food plants of the weevil. These have afforded valuable new data on food plants and parasites. Heavy incidence of the weevil in species like *Triumfetta rhomboidea*, *Sida acuta*, *Hibiscus esculentus*, *Urena lobata* and *Urena sinuata* was a common feature in most situations. The most significant result from these studies consists in the discovery of its profuse breeding in wild plants and weeds in virgin forests in a district characterized by the total absence of any cotton cultivation. These observations tend to throw considerable light on the indigenous character of the insect. It is also suggestive of the fact that a harmless native insect originally feeding and breeding in weeds and wild plants has learnt to invade and colonize in an economic plant like cotton. The discovery of heavy parasitism in some stations is another feature of great significance.

South Kanara. The general ecology of the tract is apparently similar to that in Malabar. Still this region may be deemed unique in many respects. The region forms the most extensive wooded area in the entire west coast and abounds in virgin forests particularly in the inaccessible parts of the interior. This tract characterized by heavy rainfall and red laterite soil interspersed with rolling hills and rapid streams presents great diversity in eco-climates. The entomological significance of these aspects lies in the abundance of weeds and wild plants as a source of alternate hosts pests and parasites. Coupled with this may be recorded that the region as a whole is devoid of any cultivated cottons. The present survey has been of great interest in that it has established the existence of the weevil in this tract. It has been taken from *Hibiscus esculentus* in all the localities explored. Besides, a few other species like *Triumfetta rhomboidea*, *Sida rhomboidea* and *Urena* spp. also revealed infestation in varying degrees. The incidence in the latter species was not heavy, probably because the plants were young and the season had not sufficiently advanced to build up large populations. In general, the observations have served to amplify our knowledge of the habits and distribution of the insect. On account of its occurrence in varied habitats, the insect has shown itself to be a highly adaptable species and its presence in the district is absolutely independent of cotton cultivation. Parasitism was somewhat scarce during the season. Two species of chalcids have been encountered.

Trichinopoly, Tanjore, South Arcot, Chingleput and Chittoor. A few localities in each of these five districts were investigated. To discuss a vast region so diversified is obviously difficult. Despite great differences in topographical, agricultural and meteorological conditions, they apparently present certain similarities in respect of the stem weevil problem. Besides, for the sake of brevity, it is convenient to deal with them collectively. The seasonal characteristics of temperature and precipitation show only slight variations in these districts. A characteristic of some of these districts is sudden thunder storms accompanied by high winds. The use of crop rotations, the preparation of the soil and methods of cultivation, as also the variety of crops are so varied that all gradations from careful and clean practices to those which are the very reverse thereof, exist. Some of these districts form important grain centres. Except in a taluk in Trichy and South Arcot districts, cotton at present forms only a very minor crop and its cultivation is of recent origin and is practised only in very small isolated and insignificant patches. The region as a whole compared with west coas

districts presents hot and dry conditions in summer months with the result that weeds and wild plants in uncultivated waste lands generally get parched up and killed save along river beds and channel bunds. These features have a direct bearing on the availability of food plants and uninterrupted facilities for weevil breeding. The results of the survey, however, are of importance in that it may now be safely recorded that *Pempherulus* is a common inhabitant of all these districts and that it occurs either in cotton or in one or more of its alternate food plants. At the same time it requires to be stressed that the insect does not at present constitute a serious pest of cotton in any of the localities covered by the survey. The highest level of average infestation in cotton may not even rise up to one per cent in any of the regions. In Trichinopoly and South Arcot districts, occasional stray galls caused by early attacks were noticed but live stages of the pest were in most cases absent in this part of the season. In Tanjore, Chingleput and Chittoor districts, even such gall formations were very rare and only doubtful cases of old attacks were observed. It may also be recorded that live stages of the pest have not been recovered from more than one or two localities in the region. On the other hand, it is the alternate food-plants that gave definite proof of the occurrence and comparative abundance of the pest in these districts. Particularly one species—*Hibiscus esculentus*—consistently yielded numerous stages comprising all developmental instars of the insect. Even among these plants, it is the old ones of the previous season which are almost dried up that harboured heaps of the weevils. Some sample collections of this material from Tanjore, Trichy and South Arcot imported and caged in the laboratory have given numerous adult emergences for a prolonged period of over three months. Small quantities of other food-plants collected from some moist situations such as river beds, irrigation channels or garden lands have also shown weevil attacks in varying degrees. In Tanjore district, other species such as *Triumfetta rhomboidea*, *Corchorus olitorius* and *Urena lobata* were also seen infested. In South Arcot district, *Malvastrum*, *Sida* spp., *Pavonia zeylanica* and *Triumfetta rhomboidea* showed attacks besides *H. esculentus.* In Chingleput, *Sida acuta* and *Pavonia zeylanica* conveyed heavy infestations. In Chittoor district, *Sida acuta* and *Hibiscus cannabinus* were seen attacked in addition to *H. esculentus*. Parasitism was observed in association with *H. esculentus*. *Dinarmus* sp., *Spathius critolaus*, *Eupelmus* sp., and *Entedon* sp. were encountered. The results of the survey may be considered as of utmost importance since these constitute the first positive record of the occurrence of weevil and its parasites in these districts.

Probable factors affecting incidence

Without a more thorough and prolonged investigation, it has not been possible to obtain an insight into the factors responsible for keeping the weevil partially in check in these districts. A few general observations bearing on the question can, however, be made. *Prima facie*, the distribution and abundance of the weevil are intimately associated with those of its favourite food-plants. Certain factors appear to affect the weevil at one or more stages in its life-history so that its range is limited to suitable habitats. What these factors are have not been definitely determined but the following suggestions may be set forth. Moisture in the form of rain or when present abundantly in the soil is an important factor. For the incubation of eggs and the development of early grubs, a high degree of moisture is essential. Whereas excess of moisture would be harmful to late grubs, prepupae, pupae and adults by causing heavy mortality by fungus attack, heavy rainfall with a cloudy atmosphere and moist soil would curtail the egg-laying activities of the female as the insect requires bright sunshine and fairly high temperatures for oviposition. Hence, even rainfall in excess or in wrong periods in its life-cycle will act as controlling factors. While the conditions described above may act as a handicap in west coast districts at certain seasons, the southern and central districts are influenced by a set of totally different factors. Cotton cultivation in most regions, besides being in small patches, is a recent introduction and the weevil breeding in its natural food-plants has not had sufficient opportunity to adapt itself to the new economic plant cotton. It may also be that the ecological factors, such as climatic and physical conditions, are such as to inhibit the multiplication and spread of the pest. The extreme drought of the summer months coupled with high temperatures nearly operate to exterminate the wild food-plants of the weevil except in moist and more favourable situations. Thus, generalizations (without reference to differential requirements of weevil stages), that a humid climate is favourable and that dry conditions are uncongenial, are apt to mislead since they are only partially true. These observations lend support to the laboratory findings under controlled physical conditions. Anyway, it is of interest to note that evidence is accumulating that the weevil is indigenous in origin and that its original and natural food plant is probably not cotton. Its occurrence, however, in other food plants in numbers in most districts is a source of potential danger to the spread of cotton cultivation in these districts.

Pempherulus INCIDENCE IN COTTON

The data collected under this head are based on the individual examination, according to a uniform system, of nearly 7,172 plants during the period (November 1939 to August 1940). The material was obtained from two separate fields—one in the Central Farm and the other at the Insectary. Besides, seasonal collections of country cottons from the neighbouring villages were examined by way of comparison. The results obtained have been summarized in Table I. The data gathered from the two plots of Cambodia are presented and discussed separately so as to afford evidence on the erratic incidence of the pest in two similar situations within a short distance in the same locality.

TABLE I

Crops sown in August 1939

Month	Central Farm F. No. 68				Insectary field				Remarks
	No. of plants examined	Percentage of incidence	Live stage per 100 plants	Percentage parasitism	No. of plants examined	Percentage of incidence	Live stage per 100 plants	Percentage parasitism	
November 1939	531	15·63	8·85	...	74	5·30	2·67	...	
December 1939	1170	5·21	5·21	...	135	48·89	37·04	...	
January 1940	804	21·28	15·05	0·83	465	83·01	62·37	0·69	
February 1940	742	34·40	17·74	0·75	375	83·73	69·06	...	
March 1940	504	44·05	11·31	...	261	95·79	106·90	...	
April 1940	392	52·04	2·81	...	132	99·14	6·47	...	
May 1940	150	75·33	2·00	...	560	100·00	49·46	...	
June 1940	...	No crop	...	...	305	99·00	90·50	...	
July 1940	...	Do.	...	...	344	100·00	55·23	0·52	
August 1940	...	...	...	...	138	100·00 No crop	10·80	...	

It is evident that marked divergences in the rate of infestation occurred in the two plots. The incidence in the Insectary fields has had a rapid and sudden rise in comparison with the rather slow and gradual infestation in the other.

Central Farm Plot. The first wave of influx of the weevils into the crop appears to have originated in October, although stray examinations at the time did not actually reveal many infestations. Systematic examination of these plants was commenced in November and the percentage was recorded as 15·63 for the month. All immature stages were met with and the population averaged 8·85 per 100 plants. An apparent fall in the percentage was indicated by the figure 5·21 incidence in December which may be explained as due to the limitations in the area for collection of material. The first generation seems to have reached its completion in the month as evidenced from the emergence of adults. By January the second generation has had its beginnings as revealed by the dominance of newly hatched young grubs. The incidence has also shown an increase to 21·28 per cent with an average live population of 15·05 per 100 plants. It is in the month of February that the live population reaches its peak as indicated by the average figure of 17·74 live stages per 100 plants. In spite of considerable overlapping of broods, the beginning of the third generation is noticeable by March when adult emergences are at their highest level. By this time there occurs a decline in population which continues through the succeeding months.

Insectary Plot. The data recorded from this plot appear to follow, in the main, the general trend of incidence indicated in the other field. Some notable deviations in the nature and degree of incidence and growth and decline in density, however, require to be stressed. The infestation in this field rapidly rises from 5·3 per cent in November to 48·89 per cent in December but yet the more advanced stages of the insect, such as prepupae, pupae and adults, have not put in their appearance. It is only in January with 83·01 per cent incidence that adults and emergence apertures begin to appear. These data indicate that the first generation has reached its culmination much later in this crop than in the former. In keeping with this phenomenon, the peak

level of live population has shifted in this plot to March as against February in the Central Farm Plot. From 69·06 live stages per 100 plants in February there occurs a rise to 106·9 in March. At this stage the intermixing of generations becomes more and more pronounced so as to render them increasingly indistinguishable. The population at this stage is at a low ebb and the density suddenly drops to as low a figure as 6·47 per 100 plants in April. Simultaneously, the third wave of incidence commences so as to reach its culmination in June. An incipient intermixed fourth generation may be said to be undergone by the weevil during July and August when live populations reach their lowest level.

These divergences notwithstanding, it may be generalized that the weevil passes through nearly three generations by the end of the cotton season in April with a peak of population density during the second wave of incidence which might fall in either February or March. After this period there occurs a gradual decline in pest population brought about by a complex of ecological factors among which high temperatures and low humidities, pronounced gumming, age of the crop and, to a slight extent, parasitic forces form the more important. Favourable weather conditions, however, appear to exert some influence in producing intermittent rises in population.

Off-seasonal studies—country cottons

Small quantities of country cottons (Karunganni variety) to the tune of about 250 plants were obtained from neighbouring localities and examined during the months August to October 1940, as shown in Table II below.

Table II

Month	No. of plants examined	Percentage of infestations	Live stages per 100 plants	Emergence apertures	Percentage of parasitism	Remarks
August 1940	129	34·10	24·80	7	...	Material from different localities and fields
September 1940	67	31·34	49·25	9	...	
October 1940	54	50·00	9·23	2	...	

It may be evident from the data that the rate of infestations is comparatively low and that the live populations were very poor. The figure 9·23 stages per 100 plants for October shows that the population was at its lowest level at this part of the season. As seen from the scarcity of emergence apertures and the absence of more advanced stages such as pupae and adults, it is evident that the development of the insect is considerably arrested at this stage. These findings are of importance in showing that country cottons do not constitute a very serious factor as a source of reinfestation for the succeeding seasonal crops.

Alternate food-plants

A total of 7,779 plants has been individually examined under the category during the period. These do not include large collections of plants examined on the spot while on tour in the districts. Particular mention has to be made among the latter class of a large lot of 367 plants from Malabar which formed excellent material for both pest and parasites. A systematic collection of about 23 distinct species of plants has been made from various localities such as Kuniamuthur, Thondamuthur, Telungupalayam, Perur, Narasapuram, Semmedu, etc., all within a radius of about 25 miles from Coimbatore. The results of studies on this aspect of the problem have been embodied in the form of a paper [Krishna Ayyar 1940]. Therefore, only a brief discussion of this subject is attempted here so as to indicate the progress made during the extension period. Table III furnishes a summary of the more important data gathered during the period.

It may be noted from Table III that out of a total of 23 species, as many as 16 have shown weevil attacks. Among these, there is only one species—*Corchorus trilocularis*—which has to be regarded still as a doubtful host of the weevil. All the others are definitely known to be true food-plants. These plants together with two species of plants already known to be its genuine hosts namely *Hibiscus esculentus* and *Hibiscus cannabinus* make a total of 18 alternate food-plants of the weevil. Complete data on every species relative to incidence, population and parasitism, are provided in Table III. It may be mentioned in this connection that previous to these studies, no data were available for any species and the existence of alternate food-plants was itself regarded as open to question. Further, four other species, *H. micranthus*, *H. surattensis*, *Melochia corchorifera* and *C. trilocularia* have to be classified as provisional hosts since typical infestations like those of *Pempherulus* have often been noted in them. Four species among these, viz. *P. zeylanica*, *C. acutangulus*, *S. cordifolia* and *U. sinuata* constitute new host records discovered during the period under review. The nature and extent of infestation can

be readily appreciated from the data on maximum and average percentage of incidence, live stages and parasitism. It may be evident that *T. rhomboidea* is unique in having a high average rate of infestation and parasitism. Other species which have consistently revealed appreciable infestation and parasitism are *S. acuta*, *H. esculentus*, *C. olitorius*, *S. spinosa*, *H. vitifolius*, *S. glutinosa*, and *Althaea*. The progress recorded in this aspect of study forms one of the most important and striking developments in the investigation under discussion. The discovery of several host plants and the varying degrees of intensity in infestations raised the question of biological races in the species. A few observations in the field coupled with some tests in the laboratory on oviposition, longevity, growth and development of the weevil populations from various food-plants showed marked divergences in behaviour and habits among them. Though morphologically the insects from various hosts were identical, the populations seemed to differ in host and habitat preferences. Probably these physiological differences have resulted from adaptations of the weevil and its life activities to the seasonal and other ecological conditions of the food-plant. There appears, however, to be sufficient indication to suspect the occurrence of physiological races in the species. This phenomenon has a practical bearing on its control.

TABLE III

Alternate food-plants examination 1939-40

Name of plant	Total number	Percentage of infestation		Live stages per 100 plants		Percentage of parasitism	
		Average	Maximum	Average	Maximum	Average	Maximum
Triumfetta rhomboidea	3458	58·73	80·46	104·07	331·30	5·10	44·64
Hibiscus vitifolius	396	14·62	26·00	9·59	34·00	2·50	16·69
Malvastrum coromandelianum	664	5·72	26·08	0·06	6·66	...	...
Altheae rosea	240	36·25	43·85	91·25	100·00	2·28	2·28
Sida spinosa	113	8·84	40·00	...	...	...	...
Sida acuta *	329	6·16	35·00	0·91	10·00	66·60	66·60
*Corchorus acutangulus**	141	3·54	75·00	4·25	75·00	...	...
Pavonia zeylanica *	336	5·02	33·30	5·35	11·49	18·10	11·11
Sida rhomboidea	144	6·25	20·00	1·38	10·00	...	...
Hibiscus ficulneus	195	0·05	5·00	...	...	...	...
Sida glutinosa	256	11·71	33·33	4·73	50·00	...	...
Corchorus olitorius *	383	3·13	28·50	2·35	49·10	11·11	33·33
Urena lobata	11	...	...	...	...	...	...
Sida cordifolia †	57	1·75	100·00	3·50	200·00	...	...
Urena sinuata	115	3·47	14·29	...	...	...	...
Hibiscus micranthus	45	2·22	33·33	...	...	...	...
Hibiscus surattensis	23	...	...	...	...	...	...
Corchorus trilocularis	240	5·00	14·40	...	...	...	...
Hibiscus manihot	4	...	...	...	...	...	...
Corchorus fascicularis	1	...	...	...	...	...	...
Abutilon hirtum	36	...	...	...	...	...	...
Abutilon indicum	32	...	...	...	...	...	...
Triumfetta rotundifolia	100	...	...	...	...	...	..
Total	7779						

* Includes August, September and October, 1939
† Includes September and October. 1939

Parasitism—cotton field parasites

Along with the study of pest incidence, data on parasitism were also sought to be gathered. As may be seen from Table I, parasitism in the crops examined was scarce during the short period and was observed only in a few instances in the cotton field. They were encountered only in January and February as also later in the season in July. The highest percentage recorded was only 0·83 in January in field No. 68, Central Farm. Natural scarcity of parasites coupled with the limited area under investigation and the restricted quantities of material that could be tackled may have, to some extent, contributed to the somewhat meagre records obtained under this head.

Parasitic fauna

Three species of parasites were met with during the period, namely *Euderus pempheriphila*, *Rhaconotus* sp., and *Spathius critolaus*. The study of the biology and distribution of the parasites, however, have been continued as opportunities arose and all available information under this head has been embodied in the form of a paper and presented before the second conference of Scientific Workers on Cotton, 1941, Bombay. Therefore, only such observations as have been made during the period under review are outlined in this report.

Euderus pempheriphila. Three specimens were obtained in the form of two larvae and one pupa during January-Febuary. The life-cycle was particularly elucidated with a few records of maximum longevity.

Rhaconotus sp. This species was encountered only in a single instance and that in the form of a cocoon. The adult female was carefully reared out which was later induced in captivity to reproduce parthenogenetically. The progeny were all males.

Spathius critolaus. This species was systematically collected and reared on its alternate hosts during the entire period. A total of 1,893 parasites (Table V) has been obtained.

TABLE IV

Seasonal incidence of alternate host plant parasites

Month	Entedon pempheridis	Dinarmus santeri	Spathius labdacus	Spathius critolaus	Rhaconotus cleanthes	Euderus Pempheriphila	Aplastomorpha calandrae	Bruchocida orientalis	Doubtful chalcids	Total
November 1939	3	...	2	...	2	...	...	...	...	7
December 1939	8	3	1	...	...	...	...	...	...	12
January 1940	7	...	...	...	...	...	...	...	...	7
February 1940	23	...	1	1	...	...	...	...	...	25
March 1940	8	2	4	...	...	...	...	...	...	14
April 1940	...	...	...	...	...	...	...	...	1	1
May 1940	21	5	...	...	1	...	...	1	1	29
June 1940	14	14	1	3	3	...	...	...	...	35
July 1940	11	10	...	...	1	1	...	...	...	23
August 1940	17	7	...	...	...	...	...	...	...	24
September 1940	2	...	...	...	...	...	5	...	...	7
October 1940	8	5	5	...	...	...	...	...	...	18
November 1940	13	5	5	1	...	...	...	...	...	24
Total	135	51	19	5	7	1	5	1	2	226

Among these, 1,358 adults inclusive of 528 males have been reared in the laboratory on its alternative host, the amarantus stem weevil. The life-cycle varied from the minimum of 16·93 days in June to 26·68 days in February. The other alternate host—*Sinoxylon sudanicum*—in outdoor cages yielded a total of 535 adults with 317 females. Table V presents details on these aspects. Since this species happens to be the most promising of cotton field parasites, attention was centred on a study of the problem of host parasite relationship which has a vital bearing and application on its utility for purposes of biological control. The results of these studies were presented in the form of a paper read before the Entomological Society of India (1941). These may be briefly summed up as follows :

The parasite female under the conditions of experiment was capable of distinguishing the true from false hosts for parasitization. Its responses,

however, to sensory impressions, such as shape, texture and odour, were rather complex and that no single factor by itself was responsible for the resulting behaviour of the parasite. Besides, the parasite prefers and accepts advanced host grubs beneath a covering. Prepupae and pupae are rejected. Earlier instar grubs are not unacceptable. The species is able to discriminate between parasitized and unparasitized hosts. Superparasitism is not uncommon and is probably influenced by regularity in the availability of hosts particularly in relation to the number and nature of hosts. The female attacks its normal hosts in the laboratory both when presented in normal host plants and non-host plants. No case of multiparasitism has been observed in nature. The studies are highly suggestive of the possible existence of two or more physiological races of the parasite species. These findings are of importance in its manipulation for the biological control of the weevil.

Parasitism in alternate host plants. Parasitism has been observed in association with six species of alternate food-plants, namely *T. rhomboidea*, *H. vitifolius*, *S. acuta*, *Corchorus olitorius*, *Althaea rosea* and *Pavonia zeylanica*. The discovery of parasites in association with the last two species of plants, namely *Althaea* and *Pavonia* was made for the first time during the extended period of investigation.

TABLE V

Emergence of Spathius critolaus

(Reared in laboratory on *Hypotixus* grub)

(*Consolidated statement—November 1939 to December 1940*)

Month	From outdoor cages					Reared in laboratory in amaranthus grubs					Average life-cycle in days
	Male		Female		Total	Male		Female		Total	
	Winged	Wingless	Winged	Wingless		Winged	Wingless	Winged	Wingless		
November 1939	...	...	...	...	...	...	...	...	...	...	...
December 1939	...	...	2	...	2	...	26	2	19	47	22·53
January 1940	...	...	...	1	2	...	24	...	67	91	25·06
February 1940	...	5	...	5	10	...	20	1	78	99	26·68
March 1940	...	...	...	...	...	...	17	...	41	58	18·60
April 1940	...	10	...	5	15	...	1	...	12	13	20·23
May 1940	...	10	...	14	24	...	22	8	9	39	16·93
June 1940	...	31	...	38	69	...	61	7	43	111	17·70
July 1940	...	53	4	68	125	...	102	21	121	244	20·57
August 1940	...	38	4	50	92	...	125	22	192	339	18·49
September 1940	...	25	2	56	83	...	68	5	85	158	19·00
October 1940	...	45	3	65	113	...	62	13	87	162	18·11
Total	...	218	15	302	535	...	528	76	754	1,358	20·03

Parasitic fauna and seasonal incidence. A total of 226 parasites, consisting of 135 *Entedon*, 51 *Dinarmus*, 19 *Spathius labdacus*, 7 *Rhaconotus cleanthes*, 5 *S. critolaus*, 5 *Aplastomorpha*, 1 *Euderus*, 1 *Bruchocida* and 2 doubtfu chalcids, was obtained from the source. Table IV provides data on their numerical strength and seasonal incidence.

From Table IV it may be evident that *Entedon* is the most numerous among parasites and occurs throughout the year save in April. *Dinarmus* which comes second in number also occurs all round the year but appears to be rare in the season January to April and is entirely absent in the months January and February. *Spathius labdacus* does not seem to occur during the season April to September. Other species occur only occasionally and in small numbers. The biology of these species has been partially elucidated and some new data on their distribution obtained. These have been presented in a paper read before the Cotton Workers Conference [Krishna Ayyar 1941]. Since data gathered prior to these studies and those obtained

during this period are not easily separable, an account of the biology of the species is not included in this review.

Nematode parasites. These parasites were obtained in November in association with *T. rhomboidea.* These have been for the first time recovered from the species *Malvastrum* during the present studies.

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PHYSICO-CHEMICAL AND MINERALOGICAL STUDIES OF BLACK AND RED SOIL PROFILES NEAR COIMBATORE

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(With one text-figure)

The black and red soils of India represent two large groups of soils. They often occur together in the same district. The black soils are comparatively richer in their contents of calcium carbonate, possess a higher degree of colloidality, are much more adhesive, expand greatly when wet and contract considerably when dry [Viswanath, 1939]. Raychaudhuri [1936 ; 1939 ; 1941], in connection with his work on associated black and red soils of Nyasaland Protectorate, British Central Africa, has discussed, at length the contrasted properties of such associated soil types. Basu [1939] suggests that the black and red soils of India form two distinct soil types which have evolved as a result of local variations in pedogenic factors. Sen [1939] holds the view that the black soil is the transported red soil from the elevated places subsequently converted black *in situ* after its deposition in the valley bottoms and that iron in the soil plays the main rôle in this colour change. Marchand [1924] has discussed at length the question of the occurrence of dissimilar soils associated with similar rocks in South Africa. He points out that the texture of a soil will depend on the relative porportions of kaolin, silicic acid and ferric hydroxide and these proportions are not necessarily the same for all rocks of similar mineralogical make-up. The presence of iron compounds in the rock makes the resulting soil more open and easily drained. Moreover, sometimes an admixture of sandy material, perhaps from an adjacent quartzite or sandstone takes place and the resulting soil is a red heavy loam. Marchand [1924] has, however, advanced no supporting evidence in favour of his theory. Mention may be made in this connection of the views of Ramiah and Raghvendrachar [1936] who believe that the black soils occurring side by side with the red soils have not been derived from the latter ; the black soils are probably formed from rock containing lime and soda-lime felspar, while the red soils are formed from rocks containing potash felspar. In the present work, the physico-chemical and mineralogical properties of soil samples of two contrasted profiles, one red and one black, have been compared. The climatological data of the locality are given in Table I and the morphological descriptions of the two profiles are given in Tables II and III.

Table I

1. *Locality*—Sravanampatti Hillock on the left hand side of Satyamangalam Road from Coimbatore to Satyamangalam.

2. *Climate*—

Temperature

	Jan.	Feb.	Mar.	April	May	June
Mean min. °F.	64·3	66·0	69·9	73·5	73·5	71·8
	July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	70·9	70·9	70·8	70·6	68·9	65·7
	Jan.	**Feb.**	**Mar.**	**April**	**May**	**June**
Mean max. °F.	86·4	91·5	96·1	97·3	94·8	89·3
	July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	87·5	88·1	89·1	88·0	85·8	84·7

Humidity—R. H. per cent

	Jan.	Feb.	Mar.	April	May	June
Mean of 8 hrs.	82	80	78	79	80	80
	July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
	81	83	83	84	83	82

Rainfall in inches—

Jan.	Feb.	Mar.	April	May	June
0·59	0·32	0·48	1·44	2·36	1·66
July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
1·46	1·13	1·51	6·41	3·75	1·18

Total annual rainfall 22·29 in.

3. *Altitude*—1,400–1,500 ft. above sea level.

4. *Surface features*—Undulating. Profile taken from a cutting near roadside.

5. *Nature of natural and cropping vegetation*—Natural vegetation : Thorny quadrangular euphorbia. Cropping vegetation : *Jowar* (mainly), also cotton and korra. In some places groundnut is grown.

6. *Soil-water conditions*—Free surface drainage. Maximum depth of water table : 25–30 ft. in droughty period. Minimum depth of water table : 20–25 ft. in the rainy season.

7. *Character of parent material*—Gneissose granites which are often micaceous (mainly biotites) Also pegmatitic materials.

TABLE II

Black cotton soil (About 6 miles N. E. of Coimbatore)

(Date of collection 24 Dec. 1939)

Horizon	Thickness	Description of each horizon				Sample depth	Amount of concretions per cent	Additional remarks
		Colour	Texture	pH in field	Structure			
1	0—2 ft.	Black	Clayey	8·0	Cloddy	0—2 ft.	0	...
2	2—4 ft.	Black mixed with white calcareous nodular concretions	Gravelly	7·9	Compact and gravelly	2—4 ft.	70	Moist in the sub-soil

TABLE III

Red soil (About one furlong S. E. of Sravanampatti Hillock on the right side of Satyamangalam Road)

(Date of collection 24 Dec. 1939)

Horizon	Thickness	Description of each horizon				Sample depth	Amount of concretions per cent	Additional remarks
		Colour	Texture	pH in field	Structure			
1	0 in.—1 ft. 9 in.	Red	Loamy	7·4	Granular	0 in.—1 ft. 9 in.	22	Penetration of roots
2	1 ft. 9 in.—2 ft. 9 in.	Dark red	Gravelly	7·1	Gravelly	1 ft. 9 in.—2 ft. 9 in.	69	Soil mixed with gravels and pegmatitic materials
3	2 ft. 9 in.—4 ft.	,,	,,	6·9	,,	2 ft. 9 in.—4 ft.	60	Mixed with decomposed micaceous (biotite), granites and quartz and felspar particles. Pockets filled with decomposed micaceous felspars. Subsoil remains wet

EXPERIMENTAL

The experimental work and results in the present paper have been divided into the following sections :

§ I : Loss on ignition and chemical analyses of the clay fractions [A. O. A. C., 1938].

§ II : (*a*) Sodium sulphide-oxalic acid treatment for the removal of free silica, free alumina and free iron oxide [Truog, 1937].

(*b*) Determination of percentages of free alumina and free iron oxide by dye adsorption tests [Hardy and Rodrigues, 1939] :

(*i*) The Alizarin adsorption test.

(*ii*) The Diamine Skyblue and the Janus Red tests.

§ *III* : Mechanical analyses of soil samples [Robinson, 1933].

§ *IV* : The pH was determined by Kuhn's barium sulphate method, the base exchange capacity was determined by Parker's method [1929], and total exchangeable bases by Rice William's method [1929].

§ V : Determination of percentages of organic carbon [Walkley, 1935] and of total nitrogen by Kjeldahl's method in the soils.

§ *VI* : Determination of percentages of air-dry moisture, maximum water-holding capacities and other physical properties of soils obtained by Keen-Raczkowski Box experiment [Keen and Raczkowski, 1921].

§ *VII* : Mineralogical analyses of heavy fractions of fine sand of the soil samples [Milner, 1940].

§ *VIII* : Study of dehydration curves of the clay fractions [Kelly and coworkers, 1936; 1939].

RESULTS AND DISCUSSIONS

§ *I. Chemical analyses of the clay fractions* : The results in Table IV show that with both black and red soil profiles, the $\frac{SiO_2}{Al_2O_3}$ ratio of the clay fraction increases as we go down the profiles. It is also found that the ratios of $\frac{SiO_2}{Al_2O_3}$ and $\frac{SiO_2}{Al_2O_3+Fe_2O_3}$ are higher for the black clay fractions than for the red. This is similar to the observations of Mukherjee and Mitra [1939] on the hydrogen clays obtained from a red laterite soil and a black cotton soil from southern India. The results also corroborate the findings of Raychaudhuri [1941] on Nyasaland soils and of those of Van der Merwe [1935] on South African soils.

TABLE IV

Chemical composition of clay fractions

Colour of soil profile	Soil No.	Depth (in.)	Oven-dry basis					
			Per cent loss on ignition	Per cent SiO_2	Per cent Al_2O_3	Per cent Fe_2O_3	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$
Black	184p	0—24	13·65	50·96	19·24	10·36	4·50	3·38
	185p	24—48	15·06	52·40	18·19	9·68	4·90	3·66
Red	186p	0—21	11·80	45·77	28·84	13·32	2·70	2·08
	187p	21—33	13·65	45·02	25·95	12·75	2·95	2·24
	188p	33—48	12·73	46·35	26·62	13·36	2·96	2·24

§ II : Determination of free silica, free alumina and free iron oxide in the soils and in the clay fractions

Tables V and VI show that the percentages of free silica as determined by Truog's method increases as the depth of the soil profile increases. The percentages of free silica are higher in the black soil than in the red. It is found that the percentages of free alumina as determined by Truog's method are higher in the black soil, whilst the percentages of free iron oxide are higher in the red soil. There is no regular variations of the percentages of free alumina and free iron oxide down the depths of the profiles. The percentages of free silica in the clay fractions are, however, higher in the red soil.

TABLE V

Treatment of soils by Truog's method for dissolving free oxides of silica, aluminium and iron

(Oven-dry basis)

Colour of soil profile	Soil No.	Depth (in.)	Percentages of constituents dissolved by Truog's method		
			SiO_2	Al_2O_3	Fe_2O_3
Black	184p	0—24	3·17	0·92	2·81
	185p	24—48	3·52	1·71	2·30
Red	186p	0—21	1·38	0·43	4·51
	187p	21—33	2·57	0·21	7·05
	188p	33—48	3·50	0·41	6·72

TABLE VI

Treatment of clays by Truog's method for dissolving free oxides of silica, aluminium and iron

(Oven-dry basis)

Colour of soil profile	Soil No.	Depth (in.)	Percentages of constituents dissolved by Truog's method		
			SiO_2	Al_2O_3	Fe_2O_3
Black	184p	0—24	3·57	4·80	6·52
	185p	24—48	3·69	6·63	5·80
Red	186p	0—21	4·42	7·97	12·85
	187p	21—33	4·64	4·29	11·20
	188p	33—48	4·73	6·09	11·68

Table VII shows that the quantities of free alumina and free iron oxide as obtained by Hardy's alizarin adsorption method are higher in the black soil. On comparing these results with the data in Table V, we see that so far as the relative order of percentages of free alumina are concerned, the general agreement between the data obtained by Truog's method and by Hardy's alizarin adsorption method is fairly satisfactory. If, however, we compare the data of free iron oxide it is found that whilst by Truog's method the percentages of free iron oxide is higher in the red soil, by Hardy's alizarin adsorption method the percentages of free iron oxide is higher in the black soil. This point requires further investigation. It is also found, on a comparison of Tables V and VII, that with red soils the percentages of free alumina are higher as obtained by Hardy's method, than obtained by Truog's method. On the other hand, with red

oils the percentages of free iron oxide obtained by Hardy's method are lower than that obtained by Truog's method. This is in agreement with the findings of Raychaudhuri and Sulaiman [1940.] Table VIII shows the comparable results of dye tests on the black and red soils. The results show that the diamine-sky-blue uptake is higher with the red soil. On the other hand, the uptake of Janus red and of alizarin by ignited and fresh materials is higher with the black soil. This non-agreement between the relative orders of aldsorption by the three tests is also an important matter of investigation, but is outside the scope of the present work.

TABLE VII

Values in percentages of original whole soil by Hardy's alizarin adsorption method

(Oven-dry basis)

Colour of soil profile	Soil No.	Depth (in.)	Free Al_2O_3	Free Fe_2O_3
Black	184p	0—24	3·59	6·11
	185p	24—48	18·82	5·45
Red	186p	0—21	0·61	2·22
	187p	21—33	0·30	4·47
	188p	33—48	0·51	4·55

TABLE VIII

Comparable results of dye tests on black and red soils

(Values in dye units absorbed per gm. air-dry soil)

Colour of soil profile	Soil No.	Depth (in.)	Alizarin uptake		Diamine-sky-blue uptake			Janus red uptake
			Ignited	Fresh	Boric	Phosphatic	Difference	
Black	184p	0—24	34	90	65	51	0	1360
	185p	24—48	180	79	53	42	0	1330
Red	186p	0—21	6	33	91	60	13	606
	187p	21—33	3	66	107	52	38	1052
	188p	33—48	5	67	120	60	42	1224

Tables IX and X show the base exchange capacities of both the black and red soils and clay fractions as also of the corresponding residues after treatment with sodium sulphide-oxalic acid. It will be found that with both soils and clay fractions the base exchange capacities decrease after Truog treatment. This is in agreement with the observations of Nagelschmidt, Desai and Muir [1940] who have shown that the base exchange capacities of both the clay fractions from black cotton soil and a red earth from Hyderabad-Deccan, decrease after treatment with hydrogen sulphide [Drosdoff and Truog, 1935]. The recently published paper of Mukherjee, Mitra and Banerjee [1942] indicates also that the base exchange capacities of clay fractions show a general tendency to decrease after removal of free silica and free sesquioxide components.

Tables IX and X also show that the base exchange capacities of the residues from the black soils and the black clay fractions are higher than those of the red ones.*

TABLE IX

Influence of sodium sulphide-oxalic acid treatment on base-exchange capacity of soils

Colour of soil profile	Soil No.	Depth (in.)	Base-exchange capacity in m. eq. per 100 gm. oven-dry soil	
			Before treatment	After treatment
Black	184p	0—24	39·4	22·5
	185p	24—48	25·3	17·9
Red	186p	0—21	7·6	7·4
	187p	21—33	15·6	12·3
	188p	33—48	12·8	11·5

TABLE X

Influence of sodium sulphide-oxalic acid treatment on base exchange capacity of clays

Colour of soil profile	Soil No.	Depth (in.)	Base-exchange capacity in m. eq. per 100 gm. oven-dry clay	
			Before treatment	After treatment
Black	184p	0—24	80·8	63·5
	185p	24—48	76·0	60·0
Red	186p	0—21	33·8	33·0
	187p	21—33	34·4	33·5
	188p	33—48	36·0	35·0

§ *III: Mechanical analyses of soil samples*

Table XI shows that the percentages of clay fractions are higher with the black soils than with the red ones at corresponding depths. The percentages of coarse sand of the red soil are, on the other hand, much higher than those of the black soils at corresponding depths. These results are in agreement with the findings of Mukherjee and Mitra [1938].

* Reference may be made in this connection to the recently published works of Raychaudhuri, Sulaiman and Basuraychaudhuri [1941]

TABLE XI

Mechanical composition of soils expressed as percentages of air-dry soils (2 mm. sieve)

Colour of soil profile	Soil No.	Depth (in.)	Air-dry moisture (per-cent)	Coarse sand (per-cent)	Fine sand (per-cent)	Silt (per-cent)	Clay (per cent)
Black	184p	0—24	4·8	26·8	19·5	10·0	38·4
	185p	24—48	4·4	26·2	22·8	8·6	36·5
Red	186p	0—21	2·1	48·0	26·5	7·0	16·4
	187p	21—33	2·8	38·5	19·4	6·4	32·4
	188p	33—48	3·0	42·4	17·8	9·2	26·6

§*IV* : p*H*, *base exchange capacities and total exchangeable bases in the soils*

The data in Tables XII and XIII show that the base exchange capacities of the black soils and clays are higher than those of the red ones, and also that the base exchange capacities of the black soil decrease down the profile whilst, with the red soil, the base exchange capacities show a maximum at an intermediate depth. From Table XIII it will be found that in the case of the black clay fractions, as the $\frac{SiO_2}{Al_2O_3}$ and $\frac{SiO_2}{Al_2O_3+Fe_2O_4}$ ratios increase down the depth of the profile, the base exchange capacities decrease. In the case of the red clay fractions, however, the opposite behaviour is noticed.

TABLE XII

p*H*, *exchangeable bases and percentages base saturation*

Colour of soil profile	Soil No.	Depth (in.)	p*H*	Per cent $CaCo_3$	M. eq. of total ex-change-able bases per 100 gm. oven-dry soil (X)	Base ex-change capa-cities in m. eq. per 100 gm. oven-dry soil (Y)	Per-cent base satu-ration $\left(\frac{x}{y}\times 100\right)$
Black	184p	0—24	8·0	7·3	103·0*	39·4	*
	185p	24—48	7·9	29·0	102·9*	25·3	*
Red	186p	0—21	7·4	*Nil*	9 2*	7.6	*
	187p	21—33	7·1	*Nil*	12·2	15·6	78
	188p	33—48	6·9	*Nil*	11·3	12·8	88

*The percentages of carbonate in these oils was considerable and it appears that Rice William's method of determining the total exchangeable basis by carbonate correction is not applicable to such cases

TABLE XIII

Molecular ratios and base-exchange capacity of clay fractions

Colour of soil profile	Soil No.	Depth (in.)	$\frac{SiO_2}{Al_2O_3}$	$\frac{SiO_2}{Al_2O_3+Fe_2O_3}$	Base-exchange capacity in m. eq. per 100 gm. oven-dry clay
Black	184p	0—24	4·50	3·38	80·8
	185p	24—48	4·90	3·66	76·0
Red	186p	0—21	2·70	2·08	33·8
	187p	21—33	2·95	2·24	34·4
	188p	33—48	2·96	2·24	36·0

These results are in agreement with those observed by Raychaudhuri [1941] and with the findings of Mukherjee and Mitra [1939].

§ *V* : *Percentages of organic carbon and of total nitrogen in the soils*

The results in Table XIV show that for similar depths the percentages of organic carbon are in general somewhat higher in the black soil than in the red ones. The percentages of total nitrogen, however, appear to be similar. Also the C/N ratios are somewhat higher for the black soils than for the red ones. A sample of black soil on being treated exhaustively with hydrogen peroxide still remained substantially black, although the intensity of black colour faded somewhat. This indicated that the organic matter is not fully responsible for the black colour of the soil [Viswanath 1939 and Raychaudhuri, 1936].

TABLE XIV

Percentages of total organic carbon and of total nitrogen of soil

Colour of soi profile	Soil No.	Depth (in.)	C (per cent)	N (per cent)	C/N
Black	184p	0—24	0·810	0·055	14·72
	185p	24—48	0·495	0·042	11·79
Red	186p	0—21	0·410	0·040	10·25
	187p	21—33	0·516	0·051	10·11
	188p	33—48	0·259	0·037	7·00

§ *VI* : *Percentages of air-dry moisture, maximum water-holding capacities and other physical properties*

Table XV shows that the apparent density is somewhat lower for the black soil than for the red ones, whilst the reverse is true of maximum water-holding capacity, percentage pore space and percentage volume expansion. Sen and Deb [1941] have determined a number of physical constants of laterite and red soils of India and have shown that the heavy soils possess highest moisture constants.*

*Sulaiman and Mukherjea [1942] have observed a fair linear relationship between the percentages of clay fractions of soil samples from the bottom layers of lateritic soil profiles and their maximum water-holding capacities

TABLE XV

Keen-Raczkowski Box experiment

Colour of soil profile	Soil No.	Depth (in.)	Air-dry moisture per cent	Apparent density	Maximum water-holding capacity	Pore space per cent	Real Sp. gr.	Volume expansion per cent
Black	184p	0—24	4·8	1·41	65·30	61·18	2·39	49·11
	185p	24—48	4·4	1·21	73·43	63·01	2·36	35·50
Red	186p	0—21	2·1	1·53	36·58	43·98	2·25	21·60
	187p	21—33	2·8	1·41	52·17	56·30	2·39	33·40
	188p	33—48	3·0	1·45	49·50	53·20	2·39	29·64

§ *VII : Mineralogical analyses of fine sand fractions*

Comparatively little attention has been paid so far to the determination of the mineral compositions of soils, at any rate in India. Mention may be made of the works of Hendrick and Newlands [1923 ; 1925 ; 1928], Harrison [1933], Hart [1935], Marshall [1935 ; 1936], Pearson and Truog [1937], Jeffries [1937] and Bonnet [1939] and of Raychaudhuri and Mukherjea [1942]. It was felt desirable to compare the nature of minerals in the fine sand fractions of the black and red soils. The fine sand fractions were separated into their heavy and light fractions by shaking with bromoform (sp. gr. 2·9). The light and heavy fractions of the fine sand were weighed and the percentages of these fractions in the fine sand were calculated. Table XVI shows the percentages of the light and heavy fractions in the fine sand, the percentage loss in making the separations being also included in the same table. Table XVII shows the abundance of the various minerals in the soils which were identified in the heavy fraction. The countings of the total number of minerals and of the individual types were carried out with the help of a square micrometer scale [Raychaudhuri and Mukherjea, 1942]. The abundance of minerals in the soil samples (Table XVII) has been expressed in mg. per 1000 gm. soil and has been calculated from (*a*) the volume percentages of the minerals in the heavy fraction of the fine sand, (*b*) the specific gravities of the minerals, (*c*) the percentages of heavy minerals in the fine sand fractions (Table XVI) and (*d*) the percentages of the fine sand fractions in the total soils (Table XI). The light fractions of fine sand of all soil types consisted of quartz and felspar.

Table XVI shows that excepting the top soil sample of the black profile (184p) the percentages of light and heavy fractions in fine sand in all the samples are almost similar. Table XVII shows that the black fractions contain a much higher percentage of garnet.

TABLE XVI

Percentages of light and heavy fractions of fine sand

Colour of soil profile	Soil No.	Depth (in.)	Light fraction (per cent)	Heavy fraction (per cent)	Loss in making separations (per cent)
Black	184p	0—24	91·25	6·19	2·56
	185p	24—48	93·95	3·19	2·86
Red	186p	0—21	95·87	3·20	0·93
	187p	21—33	95·06	3·79	1·15
	188p	33—48	93·45	4·79	1·76

TABLE XVII

Weight of minerals in gm. per 1000 gm. soil

Colour of soil profile	Soil No.	Depth (in.)	Iron oxide	Hornblende	Garnet	Chlorite	Epidote	Topaz
Black	184p	0—24	14·02	41·07	53·10	3·32	9·17	..
	185p	24—48	9·75	23·69	36·20	2·67	1·40	..
Red	186p	0—21	42·56	32·25	12·40	..	5·58	..
	187p	21—33	22·17	24·02	6·75	..	5·18	1·36
	188p	33—48	16·14	51·84	8·10	7·80	1·36	..

§ *VIII* : *Dehydration curves of the clay fractions*

Nagelschmidt, Desai and Muir [1940] have studied the dehydration curves of clay subfractions from black cotton soil (12-18 in.) and red earth profiles (18-24 in.) from Hyderabad-Deccan, by the method of intermittent heating. They have shown that there is a pronounced difference in the form of the curves for red and black soils, especially between 400°C. and 600°C. From a discussion of this portion of the curves and from x-ray data, these authors have concluded that the main contrast between the two soil types is that the red clay contains predominantly kaolinite or halloysite, whereas the black clay contains mainly beidellite, a member of the montmorillonite group. It was felt desirable to examine, from this point of view, the dehydration curves of the clay fractions of the black and red soils in the present work. The procedure followed was similar to that of Kelly, Dore, Woodford and Brown [1939]. For obtaining comparative results, the weight of the samples at 50 per cent relative humidity was taken as the starting point in each case. The data in Table XVIII giving percentage loss at a particular temperature have been obtained by subtracting the moisture content at 50 per cent relative humidity of the samples from the actual loss in weight of the samples at the particular temperature. The data in Table XVIII have been plotted in Fig. 1.

In Fig. 1 the dehydration curves of the black and red soils have been compared with the dehydration curves of known clay minerals like kaolin, beidellite

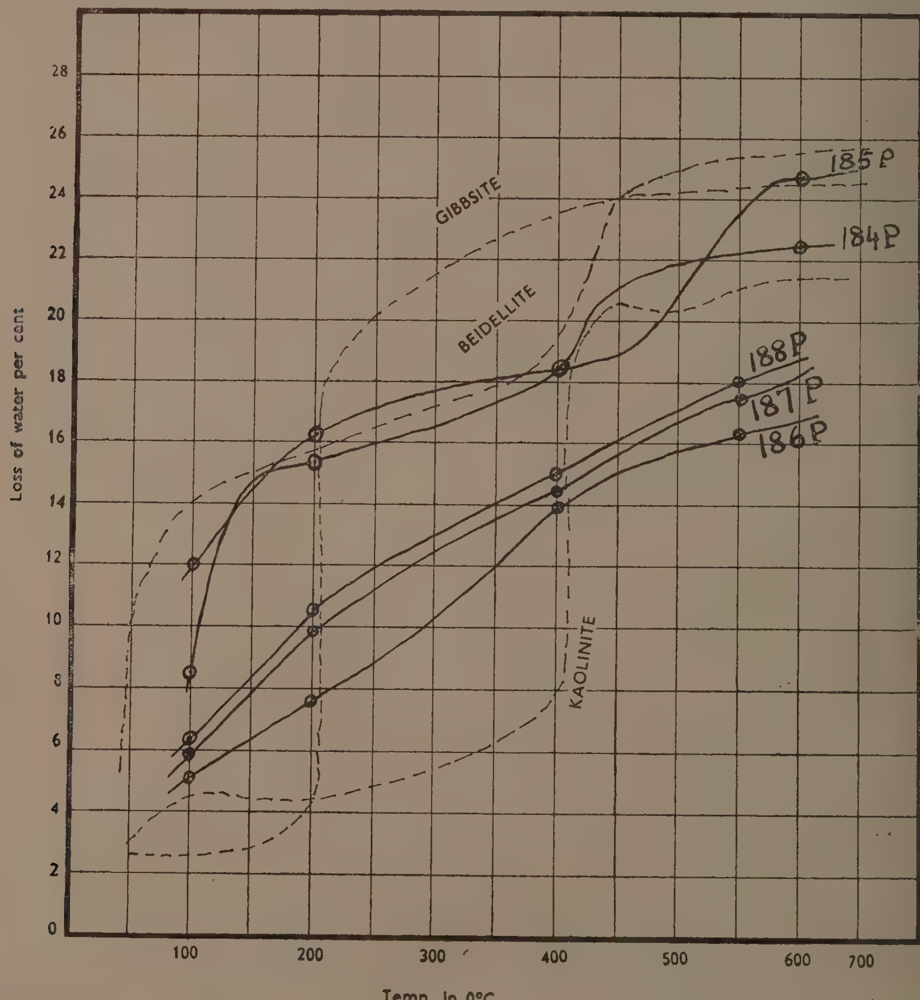

Fig. 1. Dehydration curves

TABLE XVIII

ercentages loss of water at different temperatures, elative to the moisture content at 50 per cent relative humidity

Colour of soil profile	Soil No.	Depth (in.)	105°C.	200°C.	400°C.	600°C.
lack	184p	0—24	9·25	15·50	18·79	22·32
	185p	24—48	12·06	16·28	18·71	24·68
ed	18[illegible]p	0—21	5·[illegible]8	7·60	14·12	16·61
	187p	21—33	5·89	10·11	14·46	17·60
	188p	33—48	6·25	10·21	15·17	17·92

nd gibbsite which have been plotted from the lata obtained by Kelly [1936] and by Hardy and Rodrigues [1939]. It is found that with the aolinitic group of minerals the percentage loss on gnition up to about 400°C. is very much less compared with the percentage loss on ignition of eidellitic group of minerals. It is also found that t the initial stages of heating the percentage losses n ignition of the black clay fractions (184p and 85p) are much higher compared to the similar igures of the red clay fractions (186p, 187p and 88p). From this the suggestion may be made hat the black clay fractions contain more of the eidellitic group of minerals whilst the red clay ractions contain comparatively more of the kaolinitic group of minerals.* These tentative conclusions are in agreement with the conclusions made by Nagelschmidt, Desai and Muir [1940]. The comparatively greater flatness of the dehydration curves of black and red clays at the lower ranges of temperature, as compared with typical beidellitic and kaolinitic types of clays, may be explained by the presence of gibbsite in the clay fractions. Thus, Hardy and Rodrigues [1939] have shown that up to about 250°C., gibbsite loses very small amounts of water, whilst between the temperature ranges 250°C. to 300°C. the loss of water of gibbsite is quite considerable, and they have concluded that the dehydration curve for laterite is obviously modified by its content of gibbsite.

SUMMARY

The physico-chemical and mineralogical characteristics of soil samples from two contrasted profiles of black and red soils occurring in close localities near Sravanampatti Hillock which is situated on the left-hand side of Satyamangalam Road from Coimbatore to Satyamangalam, at a distance of about 6 miles N. E. of Coimbatore, have been studied.

The results on the chemical analysis of the clay fractions show that the ratios $\frac{SiO_2}{Al_2O_3}$ and $\frac{SiO_2}{Al_2O_3 \cdot Fe_2O_3}$ are higher for the black clay fractions than for the red ones.

The percentages of free silica in the soil samples increase as the depth of the soil profile increases. It is also found that the percentages of free silica and free alumina are higher in the black soils, whilst the percentages of free iron oxide are higher in the red ones.

The data on the uptake of dyes show that the diamine-sky-blue uptake is higher with the red soil than with the black. On the other hand, the uptake of Janus red and of alizarin by ignited and fresh materials is higher with the black soil.

With both soils and clay fractions the base exchange capacities decrease after treatment with sodium sulphide-oxalic acid. The base exchange capacities of the residues from the black soils and the black clay fractions after Truog's treatment are higher than the base exchange capacities of the residues from the red soils and the red clay fractions.

The percentages of clay fractions in the black soils are higher than those with the red ones at corresponding depths. The percentages of coarse sand of the red soils, on the other hand, are much higher than those of the black soils at corresponding depths.

The base exchange capacities of the black soils are higher than those of the red ones. It is also found that the base exchange capacities decrease down the profile of the black soil, whilst with the red soil, the base exchange capacities show a maximum at an intermediate depth.

The percentages of organic carbon are somewhat higher with the black soils than with the red ones whilst the percentages of total nitrogen appear to be very similar. The C/N ratios are somewhat higher for the black soils than for the red ones.

The percentages of air-dry moisture, maximum water-holding capacities, pore space and volume expansions are, in general, higher for the black soils than for the red ones, whilst the apparent density is somewhat lower for the black soil. The maximum water-holding capacities increase with the depth of the black profile, whilst with the red one a maximum value is found at an intermediate depth.

The black soil contains a higher percentage of garnet.

From the study of the dehydration curves of the clay fractions it appears that the black clay fraction contain more of the beidellitic group of minerals, whilst the red clay fractions contain more of the kaolinitic group of minerals.

* Raychaudhuri and Basuraychaudhuri [1942] have shown that the mineral halloysite possesses higher buffer capacities than kaolin

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PRELIMINARY STUDIES ON THE WIND-BREAK EFFECT OF CROPS

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(With Plate XI)

Air movement in the layers near the ground affects a crop in two ways. Firstly, the climate of the air layers near the ground with which plants are concerned depends to a large extent on the intensity of air movement. Secondly we have the mechanical effect on plants which often results in 'lodging' when the ground is soft after rain and the hold of the root system on the soil is insufficient to resist the pressure of the wind. To the meteorologist a knowledge of the variation with height above ground of the air temperature, humidity and wind velocity is of fundamental interest, for, it is the vertical gradients of these elements which control the transfer of heat, moisture and momentum from layer to layer, in a vertical direction. Some of the main features of the micro-climate of the open and that of neighbouring crops have been discussed in recent papers [Ramdas *et al.* 1932, 1933, 1934, 1934, 1935, and 1938].

Towards the end of the year 1937 it was possible to include in the programme of the Central Agricultural Meteorological Observatory the measurement of the wind velocity at short intervals of height above ground during selected periods and in different environments. For these detailed measurements an Albrecht hot-wire anemometer was employed.

Observations with hot-wire anemometer

Just as in the Assmann Psychrometer we have a handy and very useful precision instrument for the study of air temperature and humidity, so also in the hot-wire anemometer we have a sensitive and portable instrument for the measurement of air movements in different environments. The Albrecht hot-wire anemometer has four similar thin uniform platinum wires fixed parallel to each other in one plane. Two of these are heated by a heating current. The wires form part of a Wheatstone bridge arrangement in which the galvanometer records the maximum deflection when the wind velocity is zero. This is effected by adjusting the heating current with the help of a small rheostat attached to the instrument. When the wires are exposed to the wind the hot wires are cooled and their electrical resistance is decreased. The deflection also is decreased. The readings of the galvanometer (of the pointer type) are calibrated against the wind speed. The instrument is handy (Plate XI), and sensitive to even feeble air movements. For ease of handling under field conditions, the galvanometer, the two dry batteries (one for the heating current and the other for the Wheatstone bridge arrangement), and the small rheostat for adjusting the heating current were all mounted in a suitable box, the tube carrying the hot-wire elements being kept vertically at different levels above the ground while taking the wind observations. The plane containing the wires was always exposed so as to face the wind. The calibration curve supplied by the makers was checked in the laboratory before the measurements were started.

For making a measurement the wire-elements are enclosed in the cover supplied for the purpose and the heating current adjusted so that the pointer of the galvanometer is against the zere mark. The reading of the pointer when the cover is removed is next taken and the wind velocity read off from the calibration curve.

Owing to an otherwise heavy programme of work it was not possible to introduce the hot-wire anemometer into the scheme of daily micro-climatic observations, but observations were taken during certain periods in different environments. These measurements were taken in the 'open' and inside selected crops growing near the Central Agricultural Meteorological Observatory and are sufficient for a preliminary discussion. Table I gives particulars regarding the periods and the environments in which the data were collected during the years 1937-40, the height of plants, the distance between the rows and the distance between the plants.

The suran, sugarcane and double-bean fields were periodically irrigated and had furrows between each row for that purpose.

The wind observations were taken at the epochs of minimum temperature (early morning before sunrise) and maximum temperature (afternoon about 2 P.M.) in November and December 1937 and in February 1938. Later the morning observations were discontinued.

Discussion of observations

(*i*) Table II gives the mean wind velocities in miles per hour at different levels above ground

in the 'open' and in *jowar*, suran and sugarcane, at the epochs of minimum (6 A.M.) and maximum (2 P.M.) temperature, during the period 17 to 30 November, 1937.

The wind velocities inside crops are also expressed (inside brackets) as percentages of the corresponding velocities in the open. In the morning, wind velocities are generally low, ranging from 0·5 miles per hour at 3 in. to 1·1 miles per hour at 8 ft. above ground in the open. In *jowar*, the reduction of wind varies from 35 per cent near the ground to 80 per cent at the 6 ft. level. In suran, a shorter crop, the maximum reduction is about 60 per cent between 2 and 4 ft. above ground. Inside sugarcane the reduction of wind increases rapidly with height, as in *jowar*, from 45 per cent near the ground to 80 per cent at 6 ft. above ground.

In the afternoon the wind velocities are higher, varying from two (near ground) to six (at 8 ft. level) miles per hour in the open. In *jowar* the wind-break effect is 30 per cent more than in the morning up to 2 ft. but at higher levels is of the same order as in the morning. In suran the effect is as in the morning up to 2 ft. but somewhat less pronounced at higher levels. Inside sugarcane the reduction of wind is about 85 per cent at all levels up to 6 ft.

TABLE I

Year	Month & date	Environment	Height of plants	Distance between rows	Distance between plants	Area* in acres	Epochs of observation	Remarks
1937	17 November to 12 December	Open— *Kharif jowar* . Suran . Sugarcane .	 8—10 ft. 3—4 ,, 10—12 ,,	 3 ft. 4 ,, 3 ,,	 1 ft. 3 ,, 4 ,,	 ¼ ½ ¼	Minimum and Maximum	*Jowar* harvested on 10 December 1937
1938	1 February to 14 February	Open— *Rabi Jowar* . Cotton . Sugarcane .	 4—5 ft. 3—5 ,, 10—12 ,,	 3 ft. 3 ,, 3 ,,	 1 ft. 3 ,, 4 ,,	 ¼ ¼ ¼	Minimum and maximum	*Jowar* harvested on 10 Fabruary 1938 Cotton harvested on 9 March 1938
1939	4 January to 31 March	Open— Br. cotton . *Rabi Jowar* .	 4—5 ft. 5—6 ,,	 3 ft. 3 ,,	 3 ft. 3 ,,	 ¼ ¼	Maximum .	*Jowar* harvested on 25 February 1939
1939 to 1940	11 December 1939 to 24 February 1940	Open— Cotton (dwarf) . Wheat . Tobacco . Double beans .	 2—3 ft. 2—3½ ,, 2—2½ ,, 6—8 ,,	 2 ft. 1 ,, 3 ,, 5 ,,	 2 ft. 1 to 2 in. 3 ft. 1 ,, climber	 ¼ ¼ ½ ½	Maximum .	Cotton harvested on 24 February 1940 Wheat harvested on 31 April 1940 Tobacco harvested on 30 January 1940 D. beans harvested on 20 December 1939

*(132 × 82½ ft. for ¼ acre plots. Two such plots for ½ acre plots)

TABLE II

Mean wind velocity in miles per hour during the period 17 to 30 November 1937

Height	'N' Epoch				'X' Epoch			
	Open	*Jowar*	Suran	Sugarcane	Open	*Jowar*	Suran	Sugarcane
3 in. . .	0·53	0·34 (65)	0·27 (52)	0·29 (55)	2·33	0·70 (30)	1·21 (52)	0·38 (16)
6 in. . .	0·69	0·34 (50)	0·28 (41)	0·28 (41)	2·83	0·57 (20)	1·13 (40)	0·39 (14)
1 ft. . .	0·47	0·27 (58)	0·20 (42)	0·25 (52)	3·43	0·59 (17)	1·40 (41)	0·44 (13)
2 ft. . .	0·55	0·19 (35)	0·22 (39)	0·22 (40)	2·97	0·68 (23)	1·96 (66)	0·38 (13)
3 ft. . .	0·81	0·21 (26)	0·26 (32)	0·24 (30)	3·58	0·87 (24)	2·38 (66)	0·60 (17)
4 ft. . .	1·00	0·23 (23)	0·31 (31)	0·24 (24)	3·09	0·85 (28)	2·09 (68)	0·52 (17)
6 ft. . .	1·07	0·21 (20)	0·43 (40)	0·21 (19)	5·21	1·52 (29)	3·18 (61)	0·58 (11)
8 ft. . .	1·05	..	..	..	5·66	..	..	..
No. of days .	14	14	14	14	14	14	14	14

TABLE III

Mean wind velocity in miles per hour during the period 1 to 10 December 1937

Height	'N' Epoch					'X' Epoch				
	Open	*Jowar*	Open	Suran	Sugar-cane	Open	*Jowar*	Open	Suran	Sugar-cane
3 in.	0·47	0·41 (86)	0·47	0·37 (79)	0·32 (68)	2·05	0·85 (42)	2·43	1·28 (53)	0·40 (16)
6 in.	0·51	0·38 (75)	0·48	0·39 (83)	0·35 (74)	2·25	0·74 (33)	2·62	1·42 (54)	0·40 (15)
1 ft.	0·52	0·37 (72)	0·49	0·31 (63)	0·31 (63)	1·81	0·92 (51)	2·40	1·24 (52)	0·44 (18)
2 ft.	0·65	0·28 (43)	0·66	0·31 (47)	0·28 (42)	2·62	0·74 (28)	3·02	1·67 (55)	0·38 (12)
3 ft.	0·75	0·29 (39)	0·74	0·41 (56)	0·25 (34)	3·94	0·99 (25)	4·17	1·97 (47)	0·50 (12)
4 ft.	1·04	0·31 (29)	1·02	0·47 (46)	0·27 (26)	3·61	1·13 (31)	3·90	2·22 (57)	0·41 (11)
6 ft.	1·20	0·30 (25)	1·11	0·54 (48)	0·23 (21)	4·05	0·98 (24)	4·48	3·04 (68)	0·52 (12)
8 ft.	1·36	..	1·28	..	..	4·68	..	4·92	..	..
No. of days	8	8*	10	10	10†	8	8	10	10	10

**Jowar* 1 to 8 December 1937

†Other crops 1 to 10 December 1937

(*ii*) Table III gives data (similar to those given in Table II) for the period 1 to 10 December 1937. The effects of crops in reducing wind are shown as before, sugarcane still being the most effective, particularly in the afternoon.

(*iii*) Similar observations were taken in the morning (6 A.M.) and in the afternoon in the 'open', cotton, *jowar* and sugarcane in February 1938. Table IV gives the mean wind velocities recorded in the morning.

In Table IV as the number of days of observations varied from crop to crop, the corresponding data (mean of similar number of days) in the open have been compared with those inside the crops. Cotton cuts down the wind velocity by nearly 70 per cent between 1 and 3 ft. The figures for *jowar* are as usual, but in the sugarcane crop the wind-break effect increases from 60 per cent near ground to 90 per cent at 8 ft.

Table V represents the mean wind velocity in miles per hour in the same environments as in Table IV, in the afternoon.

TABLE IV

Mean wind velocities in miles per hour in the morning (6 a.m.) in February 1938

Height	'N' Epoch					
	Open	Cotton	Open	*Jowar*	Open	Sugarcane
3 in.	0·83	0·31 (38)	0·78	0·28 (36)	0·77	0·30 (39)
6 in.	0·85	0·29 (34)	0·69	0·31 (45)	0·69	0·33 (48)
1ft.	0·92	0·28 (30)	0·72	0·31 (43)	0·72	0·32 (45)
2 ft.	0·91	0·25 (28)	0·67	0·23 (35)	0·67	0·23 (35)
3 ft.	1·03	0·25 (24)	0·83	0·24 (29)	0·86	0·22 (26)
4 ft.	1·25	0·47 (38)	1·07	0·41 (39)	1·16	0·18 (16)
6 ft.	1·42	0·97 (68)	1·25	0·65 (52)	1·38	0·17 (12)
8 ft.	1·80	1·23 (68)	1·70	0·99 (58)	1·77	0·15 (9)
No. of days	12	12*	8	8†	6	6‡

*Cotton—1 to 5 and 7 to 15 February 1938
†*Jowar*—1 to 8 February 1938
‡Sugarcane—1 to 6 February 1938

TABLE V

Mean wind velocity in miles per hour in the afternoon (2 p.m.) in February 1938

Height	'X' Epoch					
	Open	Cotton	Open	*Jowar*	Open	Sugarcane
3 in.	3·14	0·80 (25)	2·21	0·51 (23)	2·31	0·47 (21)
6 in.	3·61	0·82 (23)	1·94	0·52 (27)	2·32	0·53 (23)
1 ft.	3·89	0·77 (20)	1·80	0·65 (36)	2·11	0·61 (29)
2 ft.	4·50	0·91 (20)	2·49	0·84 (34)	2·24	0·51 (23)
3 ft.	5·19	1·15 (22)	3·12	1·34 (43)	2·95	0·61 (21)
4 ft.	5·33	2·27 (43)	2·96	2·02 (68)	3·01	0·78 (26)
6 ft.	5·94	3·41 (57)	3·50	2·76 (79)	3·21	0·83 (26)
8 ft.	6·69	4·13 (62)	4·61	2·80 (61)	4·69	0·76 (16)
No. of days	24	24*	8	8†	6	6‡

*Cotton—1 to 24 February 1938
†*Jowar*—1 to 8 February 1938
‡Sugarcane—1 to 6 February 1938

Table V shows that in the afternoon the wind-break effect inside all the crops is slightly greater than in the morning up to about 3 ft., the reduction being slightly less at the higher levels.

(*iv*) The observations of wind were confined to the afternoon after February 1938. Tables VI to XII summarize the results obtained in a number of environments surrounding the observatory during different months up to January 1940. These measurements are confined to the clear season. The periods of observations and the environments in which they were made have already been referred to in Table I, and are also indicated in Tables VI to XII. The values of the mean wind velocity in the afternoon in different environments expressed as percentage of the velocities in the open, considering all values in Tables III, and V to XII are summarized in Table XIII for the sake of a general comparison.

Mean wind velocity in miles per hour in the afternoon (2 p. m.)

Height	Table VI		Table VII			Table VIII				Table IX	
	March 1938		January 1939			February 1939				March 1939	
	Open	Cotton	Open	Cotton	*Jowar*	Open	Cotton	Open	*Jowar*	Open	Cotton
3 in.	2·63	0·71 (27)	2·55	0·70 (27)	0·67 (26)	2·52	0·81 (32)	2·63	0·63 (24)	3·54	1·27 (36)
6 in.	3·59	0·74 (21)	3·08	0·70 (23)	0·65 (21)	3·08	0·87 (28)	3·26	0·65 (20)	3·99	1·31 (33)
1 ft.	4·65	0·69 (15)	3·57	0·78 (22)	0·68 (19)	3·39	0·95 (28)	3·63	0·70 (19)	4·59	1·31 (28)
2 ft.	5·39	1·06 (20)	3·93	0·85 (22)	0·75 (19)	3·47	1·03 (30)	3·71	0·84 (23)	4·65	1·70 (37)
3 ft.	5·25	1·57 (30)	4·22	1·31 (31)	1·18 (28)	3·99	1·62 (41)	4·28	1·15 (27)	5·20	1·93 (37)
4 ft.	6·28	1·87 (30)	4·99	2·24 (45)	1·71 (34)	4·16	2·44 (59)	4·47	1·54 (35)	5·24	3·48 (67)
6 ft.	6·57	2·64 (40)	5·51	3·41 (62)	3·03 (55)	4·50	3·20 (71)	4·69	2·25 (48)	5·31	4·32 (81)
8 ft.	7·34	4·22 (58)	6·02	3·87 (64)	3·81 (63)	5·09	3·64 (72)	5·36	3·04 (57)	5·74	4·91 (86)
No. of days	8	8*	26	26†	26†	26	26§	22	22**	20	20‡

*1 to 8 March 1938
†4 to 31 January 1939
§Cotton—1 to 26 February 1939 ‡Cotton—1 to 20 March 1939
***Jowar*—1 to 22 February 1939

Table X

Mean wind velocity in miles per hour in the afternoon (2 p.m.) in December 1939

Height	Open	Cotton	Wheat	Tobacco	Open	Cotton	Wheat	Tobacco	Double-beans
3 in.	3·15	0·94 (30)	0·60 (19)	1·47 (46)	3·70	1·02 (27)	0·64 (70)	2·08 (56)	0·93 (25)
6 in.	4·10	1·00 (24)	0·59 (14)	1·86 (45)	4·58	1·03 (23)	0·62 (14)	2·50 (55)	0·95 (21)
1 ft.	4·95	1·12 (23)	0·71 (14)	2·10 (42)	5·33	1·21 (23)	0·60 (11)	2·86 (54)	0·91 (17)
2 ft.	5·55	1·95 (35)	1·19 (21)	2·53 (46)	5·92	2·25 (38)	1·06 (18)	3·42 (58)	1·03 (17)
3 ft.	6·13	3·19 (52)	2·23 (36)	3·30 (54)	6·59	3·52 (53)	2·26 (34)	4·16 (63)	1·43 (22)
4 ft.	6·54	3·94 (60)	3·15 (48)	4·06 (62)	7·03	4·51 (64)	3·27 (47)	5·27 (75)	1·63 (23)
6 ft.	7·19	5·10 (71)	5·14 (71)	5·48 (76)	7·86	5·68 (72)	5·58 (71)	6·48 (82)	2·23 (28)
No. of days	19	19	19	19*	10	10	10	10	10†

*11 to 30 December 1939 †20 to 30 December 1939

Mean wind velocity in miles per hour in the afternoon (2 p.m.)

Height	Table XI				Table XII		
	January 1940				February 1940		
	Open	Cotton	Wheat	Double beans	Open	Cotton	Double beans
3 in.	2·15	0·81 (38)	0·55 (25)	0·65 (31)	2·29	0·96 (42)	0·75 (33)
6 in.	2·52	0·96 (38)	0·58 (23)	0·78 (31)	2·60	1·06 (41)	0·88 (34)
1 ft.	2·85	1·02 (36)	0·57 (20)	0·82 (29)	3·27	1·21 (37)	0·84 (26)
2 ft.	2·89	1·32 (46)	0·73 (25)	0·91 (31)	3·71	1·57 (42)	0·95 (26)
3 ft.	2·95	2·42 (82)	1·49 (50)	0·97 (33)	3·95	3·08 (78)	1·14 (29)
4 ft.	2·90	3·22 (111)	2·18 (75)	1·04 (36)	5·01	3·87 (77)	1·42 (28)
6 ft.	3·49	3·88 (111)	2·87 (82)	1·37 (39)	4·84	4·61 (95)	1·97 (41)
8 ft.	4·42	4·32 (98)	3·87 (88)	2·59 (59)	6·12	5·48 (90)	2·82 (46)
No. of days	14	14	14	14*	10	10	10†

*11 to 25 January 1940
†1, 2, 5 to 8, 12, 15, 16 and 23 February 1940

Table XIII

The mean wind velocity in the afternoon in different environments expressed as percentage of the velocities in the open (mean of all values)

Height	*Jowar*	Suran	Sugar-cane	Cotton	Wheat	Tòbacco	Double beans
3 in.	29	52	18	32	20	51	30
6 in.	24	47	17	29	17	50	29
1 ft.	28	46	20	26	15	48	24
2 ft.	26	60	16	34	21	52	25
3 ft.	29	56	17	50	40	58	28
4 ft.	39	62	18	64	57	68	29
6 ft.	47	64	16	75	75	79	36
8 ft.	60	...	16	78	...	...	52

The ability of the different crops to reduce air movements within the extent of their respective heights is in the order sugarcane, wheat, *jowar*, double-beans, cotton, suran and tobacco. There are, however, occasions of disturbed weather when the wind velocity exceeds the limit of safety for a crop and actually lays it low, causing considerable damage. A typical instance of lodging is discussed in the next section.

Effects of high winds and heavy rains

During the period 15 September to 15 October, 1938, general lodging of the tall crops in the farm of the Agricultural College was caused by heavy rains and high winds. As some of the crops were actually under detailed observations in connection with the micro-climatic and precision observations and as the knowledge of the general meteorological and agricultural factors concerned is usully complete at Poona it may be interesting to record here briefly some of the outstanding features.

Weekly precision observations on *jowar* (variety Nilwa) were in progress from August to the middle of October when the observations had to be discontinued owing to the severe lodging of the crop. Table XIV shows the development of the crop as regards number of plants, shoots and leaves and the mean height.

Table XIV

Date of observations	Mean number of plants per metre-length of row	Mean number of shoots per metre-length of row	Ratio of shoot to plant (3)÷(2) (Tillering)	Mean number of leaves per plant	Mean height of plants in cm.
(1)	(2)	(3)	(4)	(5)	(6)
30 Aug. 1938	7·07	10·64	1·50	5·54	77·56
7 Sept. 1938	5·08	7·41	1·46	5·69	121·73
13 Sept. 1938	5·58	8·36	1·44	6·46	151·77
28 Sept. 1938	4·93	6·79	1·38	6·23	173·57

After the heavy rains of September more than 50 per cent of the crop appeared to have lodged, making it impossible to move about in the field. The lodging was not restricted to this crop; all the tall crops, *jowar*, *bajri* and sugarcane suffered, the extent of lodging varying between 50 and 75 per cent from field to field. Lodging is believed to be caused by high winds during or shortly after a wet period. In the present case lodging was first observed by the third week of September 1938, and it increased gradually, becoming quite extensive by the first week of October. During this period there was no occasion when the wind velocity had reached 50 or 60 miles per hour (heavy squalls). The few occasions when winds reached about 30 miles per hour are shown in Table XV. The data were taken from the records of a Dine's Anemograph on the tower of the Meteorological Office (120 ft. above ground), about half-a-mile as the crow flies, from the College Farm. It should be remembered too that winds at or near ground would have been much less than those indicated at a level of 120 ft.

For a better understanding of the relation between lodging rainfall and wind the following factors during the period 15 September to 14 October were examined—total rainfall, maximum rainfall in 24 hours, mean daily wind velocity and the highest wind velocity in 24 hours. Table XVI gives the values for each of the years 1933 to 1938, as well as the average values for the period 1933-37.

TABLE XV

Date	Time in hrs. (I. S. T.)	Average velocity in miles per hour	Maximum velocity in miles per hour
15 September 1938	1700 to 1800	20	26
17 ,, ,,	1330 to 1345	14	24
18 ,, ,,	1340 to 1350	16	28
22 ,, ,,	1400 to 1630	14	26
23 ,, ,,	1300 to 1900	12	25
25 ,, ,,	1500 to 1700	14	29
26 ,, ,,	1645 to 1700	20	33
5 October 1938	1100 to 1400	24	34
6 ,, ,,	0400 to 0615	20	30
6 ,, ,,	0845 to 1000	22	33
6 ,, ,,	1200 to 1545	22	37
6 ,, ,,	2130 to 2245	26	38

TABLE XVI

Meteorological factor	Mean value for the period 15 September to 14 October						
	1933	1934	1935	1936	1937	1938	Average 1933-37
Total rainfall in inches	5·07	1·28	4·08	6·03	13·51	18·95	5·99
Heaviest rainfall in one day in inches	1·96	1·09	2·81	1·72	3·01	5·36	2·12
Mean (daily) wind velocity in miles per hour	4·48	4·47	2·20	3·16	2·71	4·12	3·40
Highest (daily) wind velocity in miles per hour	8·3	11·0	5·2	5·2	6·7	9·0	7·3

It is seen that during the period under consideration the total rainfall in 1938 was 18·95 in. as against 5·99 in., the average of five years. The wind velocity was 4·12 as against 3·40, the average of five years. The part played by rain is not difficult to understand. By mid-September the plants had attained the full height so that the strain on the soil was maximum. When the top soil became wet and loose owing to heavy rainfall, it was unable to support the tall plants against the action of even the moderate winds that prevailed.

In addition to lodging, the *bajri* crop suffered also from the germination of grains and the development of roots and leaves on the standing ear-heads. The damage on this account was about 5 to 10 per cent.

The incidents referred to above emphasize the need for more detailed wind velocity measurements at levels up to about 30 ft. above ground and the exploration of methods for minimizing lodging.

ACKNOWLEDGEMENT

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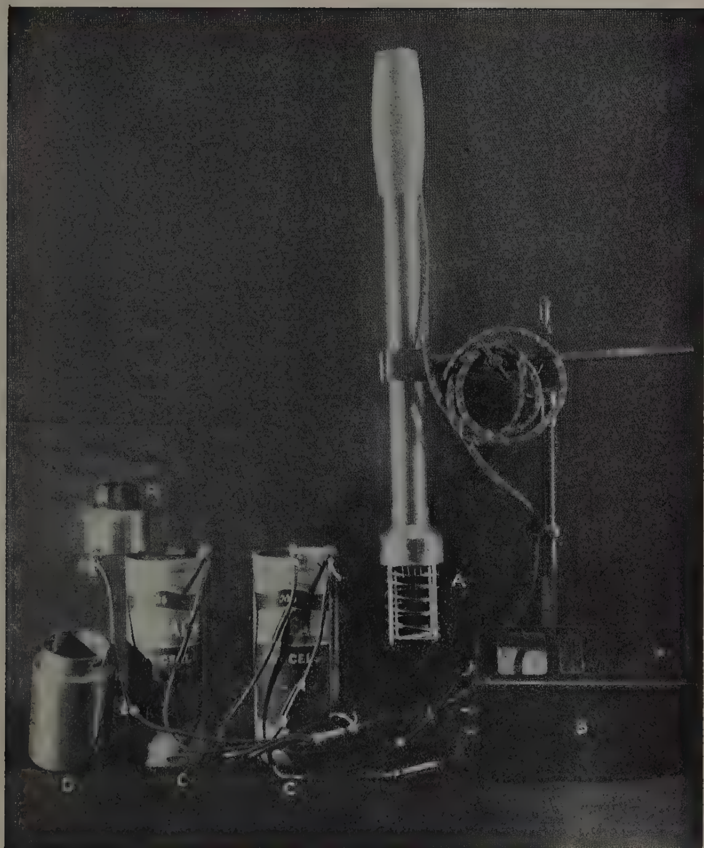

FIG. 1. Albrecht hot-wire anemometer

A—Hot-wire elements
B—Galvanometer
C—Dry batteries
D—Cover of hot-wire elements
R—Rheostat

FIG. 1. Tobacco field after the frost, showing the flaccid leaves in a drooping condition

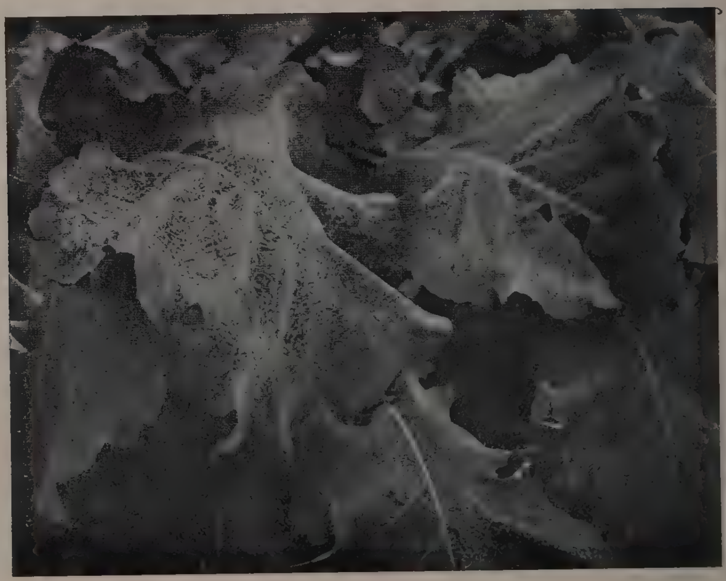

FIG. 2. a—healthy ear of wheat I.P. 4
b, c, d and e—different degrees
[of damage to wheat ears]

FIG. 3. Brassica leaves showing crystals of ice deposited on the surface

EFFECT OF FROST ON SOME ECONOMIC PLANTS OF DELHI

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(With Plate XII)

A farmer feels happy when he finds his fields covered with healthy crops. But his satisfaction is tempered with a certain amount of anxiety that he cannot be sure of his crop till he gets it home. He realizes that before the produce of his fields is ready for the market, the crop is liable to calamities such as drought, floods, wind and hail-storms, and the attacks of diseases and insect pests. No less harmful is the frost which sometimes destroys in a single night a crop which represented the labour and care of an entire season. Frosts occur rather commonly in the northern parts of India, though in certain years they are not severe enough to cause any appreciable damage. In the past, severe frosts have occurred from time to time in various parts of India and several accounts of their damage to economic plants have been published.

Previous records

Kulkarni [1911] observed at the Ganeshkhind Botanical Gardens, Kirkee, that papaya, datura, castor, plantain, guava, *kamrakh*, mango (the uppermost inflorescences only) were severely damaged. Parwar [1911] recorded his observations on the frost damage at the College Farm, Poona. He observed that solanaceous plants were badly damaged. Next in point of susceptibility were plants belonging to the Leguminosae. He further noticed that carrots, cabbage, wheat, oats, onions and lucerne remained unaffected. Joshi [1930] collected data on the damage by frost of January 1929, for the whole of the Bombay Presidency. In the sugarcane crop the damage was about 33 per cent. Late-sown and irrigated wheats and gram were damaged all over to the extent of 33 to 50 per cent. This author also estimated for some of the crops, the actual monetary loss resulting from the damage by frost. Thus tobacco-growers lost approximately, 150 rupees per acre. Young papayas, mangoes, plantains and fig trees were badly damaged and heavy losses occurred in grape gardens. While cruciferous vegetables resisted the attack, the solanaceous ones were heavily frosted. Bose [1933] recorded the effect of frost on crops at Pusa. He observed that early maturing wheats like I. P. 4, barley, lentils, gram, peas, linseed and sweet potatoes were damaged to some extent. Hulless types of barley, though not the hulled ones, showed defective fertility of the ears. Oats did not seem to be affected at all. Plants grown in dry soil were injured more severely than plants of the same or similar varieties in wet soils. Nautiyal [1934] recorded at New Forest, Dehra Dun, the frost hardiness of over one hundred forest plants in relation to their heights. The author found that the size of the plant was unimportant, in fact on the whole the average heights of the dead plants exceeded that of the survivals. Bharucha *et al.* [1935] studied the effect of frost on a number of crop plants, vegetables, fruit trees and common weeds. Their observations are in accord with those reported previously.

Frost of January 1942 at Delhi

During the second week of January, 1942 Delhi came under the spell of a cold wave of freezing intensity. On the night of January 10, a minimum temperature of 28·3°F. was recorded at the Imperial Agricultural Research Institute, New Delhi. In recent years it was only in 1935 that the minimum temperature fell to as low as 31°F. The severity of the present cold wave can well be estimated from the sheets of ice formed on the surface of stagnant waters, and the crystals of ice deposited all over the vegetation (Plate XII, fig. 3). The water in some of the exposed supply pipes froze and till 8·30 A.M. there was no outflow of water from them.

This unusually low temperature served as a natural test for determining the degree of resistance to frost of different plants. A few days after the frost attack, it was noticed that the foliage and the succulent parts of the frost-bitten plants had withered and turned brown. A peculiar feature of the damge was its patchy nature. Even in the same field, plants were affected differently, those in some patches completely escaping the attack. Similar irregularities were observed in the case of fruit trees and ornamental plants. This patchy nature of the damage may probably be ascribed to the direction of the cold wave on frosty nights. Those plants which happened to be in the vicinity of wind-breaks, such as buildings, trees and tall hedges, showed little or no injury whatsoever, for the simple reason that they did not receive the full blast of the cold wave. Nevertheless, it was noticed that certain plants, annuals as well as perennials, even though they were well exposed, resisted the

frost in all localities. It is an established fact that resistance to cold, like resistance to diseases and drought, is a heritable character. On this basis it may be concluded that these resistant plants possessed some inherent power to resist at least this particular low temperature.

It is generally held that frost causes less damage to irrigated than it does to non-irrigated crops. At the Botanical Section of the Imperial Agricultural Research Institute, a field of tobacco which had been irrigated one day before the occurrence of the frost was damaged as severely as another field irrigated about a fortnight earlier. It may be, that when the frost is comparatively heavy, as it had been this winter, the effect is the same irrespective of the moisture content of the soil.

From the temperature records given in Table I, it is evident that the weather preceding the frost was fairly warm, so that the plants had no natural 'pre-hardening' treatment. This may have contributed to the lowering of the resistance to frost and it is possible that the injury would have been less pronounced if the frost had come after a long spell of fairly low temperature.

TABLE I

Maximum and minimum temperatures recorded at the Imperial Agricultural Research Institute, New Delhi, from 1 to 12 January, 1942

Date	Temperature (°F) Max.	Temperature (°F) Min.	Date	Temperature (°F) Max.	Temperature (°F) Min.
1	70·2	40·5	7	70·2	49·2
2	70·0	39·2	8	72·8	50·8
3	70·7	39·5	9	72·8	41·2
4	71·3	37·6	10	60·5	29·0
5	70·2	42·2	11	57·0	28·3
6	70·0	43·5	12	63·0	32·0

No attempt has been made to evaluate the monetary loss resulting from the damage by frost. The object of this note is to place on record some observations on the degree of resistance or susceptibility to frost of some of the common crop plants, vegetables, fruit trees and ornamental plants of Delhi. It is hoped, this information will be useful to plant breeders, gardeners and horticulturists alike.

The following is the list of plants observed for resistance or susceptibility to a temperature of 28·3°F.

English or Indian name	Botanical name	Effect of frost
	I—Crop plants	
(a) Cereals—		
Wheat	*Triticum vulgare* Host	Early wheats which had been sown early and had just started earing were the most affected. The effect of frost was more pronounced on the ears, the leaves being injured only at the tips. In most of the affected ears all the spikelets were damaged. This is very clearly brought out in Plate XII fig. 2. It is estimated that in early wheats like I. P. 4, the damage may be to the extent of 20 per cent.
Barley	*Hordeum vulgare* L.	Barley and oats had not come in ear at the time of frost attack: slight injury to the leaf tips, however, was observed
Oats	*Avena sterilis* L. var. *culta.*	
(b) Pulses—		
Pigeon-pea (*Arhar*)	*Cajanus Cajan* (L.) Mill sp.	Highly susceptible. Leaves, flowers, pods and greater portion of the stems were badly damaged. As a matter of fact, there was 100 per cent damage
Gram	*Cicer arietinum* L.	Gram had not started flowering. Leaves and branches remained uninjured.
Lentil	*Lens esculenta* Moench	Resistant
Khesari	*Lathyrus sativus* L.	Resistant
Peas	*Pisum sativum* L.	Early flowers did not set. Slight effect on leaves also was noticed
(c) Oil seeds—		
Sarson	*Brassica campestris* L. Var. *Sarson* Prain	Rather resistant: Slight effect on flowers and young pods
Taramira	*Eruca sativa* Mill.	Slight injury to flowers
Safflower (*Kusumb*)	*Carthamus tinctorius* L.	Top shoots of some of the early plants were killed: Crop was not in flowering stage
Linseed	*Linum usitatissimum* L.	Fairly resistant but young buds were affected
Castor	*Ricinus communis* L.	Susceptible: Leaves, flowers and fruits were badly affected in most of the plants
(d) Fodder plants—		
Berseem	*Trifolium alexandrinum* L.	Leaves slightly affected: First cutting after the frost was rather poor
Lucerne	*Medicago sativa* L.	Resistant
Methra	*Trigonella Foenumgraecum* L.	Resistant
Elephant Grass	*Pennisetum purpureum* Schum.	Very susceptible: Entire shoots were killed. After about a fortnight new shoots came out from the base
Other crops—		
Sugarcane	*Saccharum officinarum* L.	Badly affected: In some of the fields not a single green leaf could be seen. Even in canes with some green leaves at the top, the central shoots had completely dried. After about a month, new shoots were seen emerging from the base. Some of the eye buds also sprouted. All this affected the quality and quantity of the juice.
Chillies	*Capsicum annuum* L. *Capsicum frutescens* L.	Both the species suffered heavily: Leaves, fruits and stems were almost entirely destroyed. However, the harvest was practically over before the frost was recorded.

English or Indian name	Botanical name	Effect of frost
Tobacco ...	*Nicotiana Tabacum* L. *Nicotiana rustica* L.	*N. rustica* was affected more as compared to *N. Tabacum*. Leaves were rendered unfit for curing (Plate XII, fig. 3). The crop had to be cut at the base. New shoots, however, came out later, but the leaf was very small as compared to that of the original crop. Recovery was more in *Tabacum* than in *rustica*
Rozelle-Hemp	*Hibiscus cannabinus* L. *Hibiscus sabdariffa* L.	Very susceptible : Both the species suffered equally. Leaves, fruits and stems were all affected
	II—Vegetables	
Onion	*Allium Cepa* L.	Not affected
Garlic	*Allium sativum* L.	Not affected
Potato	*Solanum tuberosum* L.	In some varieties the entire aerial parts were killed, but most of the plants later survived. The tubers did not show any injury at the time of harvest
Brinjal	*Solanum Melongena* L.	Very susceptible : Leaves, stems, flowers and fruits were damaged. Brown patches appeared on the fruits
Tomato	*Lycopersicum esculentum* Mill.	All parts up to the base of the plant were adversely affected : Fruits rotted : New shoots were produced later
Radish	*Raphanus sativus* L.	Not affected
Cauliflower	*Brassica oleracea* L. var. *botrytis*	Not affected
Cabbage	*Brassica oleracea* L. var. *capitata*	Not affected
Carrot	*Daucus Corota* L.	Not affected
Sem	*Dolichos Lablab* L.	Very susceptible : Entire plants damaged
Spinach (*palak*)	*Spinacea oleracea* L.	Resistant
Garden Beet or *chaukandar*	*Beta vulgaris* L.	Resistant
	III—Fruit trees	
Citron (*galgal*)	*Citrus medica* L.	Resistant
Sour lime (*Nimbu*)	*Citrus medica* L.	Resistant
Sweet lime (*Mitha*)	*Citrus medica* L.	Resistant
Orange (*Sangtara, Malta*)	*Citrus Aurantium* L.	Resistant
Peach (*Aru*)	*Prunus persica* Stokes.	Resistant
Pomegranate (*Annar*)	*Punica granatum*, L.	Resistant
Guava (*Amrood*)	*Psidium Guyava* L.	Top shoots along with the fruits were badly damaged : Fruits turned black
Fig (*Anjeer*)	*Ficus Carica* L.	Foliage severely damaged
Loquat	*Eriobotrya japonica* Lindl.	Early flowers and fruits were much affected, causing considerable loss to the growers
Papaya (*papita*)	*Carica papaya* L.	All old leaves were destroyed. There was no loss to the life of the plant. The growing shoot and the fruits escaped. Later on the effect on the fruits was also visible ; Their ripening was defective.
Plantain (*Kela*)	*Musa sapientum* Schum.	Very susceptible : Entire foliage killed
Ber	*Zizyphus Jujuba* Lamk.	Leaves and fruits of the top shoots were affected : Unripe fruits got shrunken and turned red
Mango	*Mangifera indica* L.	Frost occurred before the appearance of the flowers. Young plants were severly damaged. Foliage of the older plants was also affected.
Jaman	*Eugenia Jambolana* Lamk.	Fairly resistant : Slight damage to the leaves
Amla	*Phyllanthus Emblica* L.	In some trees entire foliage was killed : Slight damage to the fruits also was observed.

IV—Timber and ornamental plants

In the case of timber trees, the ultimate aim is to have the maximum growth in the shortest possible period. If the frost kills the top or the side shoots, the plants are certainly handicapped by being deprived of the growth which they had put up in the previous year or two. In the case of ornamental plants, yield of fruit and seed is usually no consideration, because they are grown simply for ornamental purposes. Some of them possess handsome foliage, others display beautiful flowers, still others are interesting because of their chatacteristic fruits, which however are not usually edible. When the frost damages any of the above parts, naturally the affected plants become unsightly. The following plants have been observed in this group.

English or Indian name	Botanical name	Effect of frost
(*a*) *Trees*—		
The Dita-bark tree	*Alstonia scholaris* R. Br.	Susceptible : Only leaves of the topmost branches affected
Kachnar	*Bauhinia purpurea* L.	Fairly resistant : Slight damage to the leaves and pods
Sisoo or *Shisshum*	*Dalbergia Sissoo* Roxb.	Resistant : Rarely some frosted leaves were seen
Kendu	*Diospyros montana* Roxb.	Resistant
Pipal	*Ficus religiosa* L.	Resistant
Pilkhan	*Ficus infectoria* Roxb.	Susceptible : Top shoots very badly hit
Gular	*Ficus glomerata* Roxb.	Resistant
Silver Oak	*Grevillea robusta* A. Cunn.	Highly resistant
	Jacaranda mimosaefolia D. Don.	Fairly resistant
The Sausage tree	*Kigelia pinnata* Dc.	Susceptible : Top shoots affected
Neem	*Melia Azadirachta* L.	Some of the young plants totally killed : Leaves of the older trees also frosted
Indian Cork tree	*Millingtonia hortensis* L.	Highly susceptible : Low plants badly injured
Papri	*Pongamia glabra* Vent.	Top shoots affected
Mesquite Bean	*Prosopis glandulosa* Torr.	Fairly resistant : Hedge plants were affected more than trees
(*b*) *Shrubs*—		
	Buddleia madagascariensis Lamk.	Resistant
Bottle-Brush	*Callistemon lanceolatus* Dc.	Highly resistant
Lady-of-the-Night	*Cestrum nocturnum* L.	Some of the plants got completely disfigured
	Clerodendron inerme Gaertn.	Fairly resistant
	Citharexydlon subserratum Sw.	Resistant
	Caryopteris Wallichiana Schaun.	Resistant
	Dombeya Mastersii Hook. *f.*	Foliage and flowers injured
Duranta	*Duranta Plumieri* Jacq.	Resistant
Poinsettia	*Euphorbia pulcherrima* Willd.	Leaves and red bracts were damaged
	Hamelia patens Jacq	Leaves and flowers were affected
	Holmskioldia sanguinea Retz.	Resistant

English or Indian name	Botanical name	Effect of frost
Kamini	*Murraya exotica* L.	Resistant
Oleander	*Nerium odorum* Soland.	Resistant
	Phyllanthus myrtifolius Moon.	Top leaves and twigs very susceptible
Weeping Mary	*Russelia juncea* Zucc.	Resistant
	Schinus terebinthifolius Raddi.	Highly resistant
Jaint	*Sesbania aegyptiaca* Poir.	Leaves and pods dried up
	Tecoma stans Juss.	Pods badly affected : Leaves rather resistant
Zard *Kaner*	*Thevetia neriifolia* Juss.	Foliage highly resistant : Green fruits turned black.
	Thuja sp.	Resistant
	Woodfordia floribunda Salisb.	Highly resistant

(c) *Annual flowers*—

It was interesting to note that out of about two dozen annual plants studied, only one, viz. *Tagetes erecta* L. (African Marigold) was found to have suffered heavily. The following are a few of the common annuals which proved to be highly resistant: *Althaea rosea* Cav. (Hollyhock), *Antirrhinum majus* L., (Snapdragon), *Ageratum mexicanum* Sweet, *Callistephus chinensis* Nees (Chinese Aster), *Chrysanthemum Segetum* Forsk, *Calendula officinalis* L. (English Marigold), *Centaurea Cyanus* L. (cornflower), *Centaurea Moschata* L. (Sweet Sultan), *Delphinium Consolida* L. (Larkspur) *Linum grandiflorum* Desf. (Scarlet Flax), *Petunia hybrida* x Hort., *Phlox Drummondii* Hook.

Summary

Delhi experienced a severe frost during the second week of January, when a minimum of 28·3°F. was recorded on the night of 10 January 1942. A few days after this, observations were taken on the effect of frost on some of the economic plants of Delhi. Among the crop plants, early wheats, which had been sown early (I. P. 4), pigeon-peas, sugarcane, tobacco, rozelle, chillies and castor suffered heavily. Among vegetables, *sem* and solanaceous plants such as the brinjal, tomato and potato were heavily frosted. Fruit trees, such as guavas, figs, plantains and papayas were severely damaged whereas citrus plants proved resistant. These observations mostly confirm those of workers in other places. In the group of plants usully classed as 'ornamental and timber plants', a number of plants were found highly resistant. It was interesting to note that out of about two dozen annual flowers observed, only one, viz., *Tagetes erecta* (African marigold) was found to have suffered heavily. The frost hardiness under Indian conditions of a number of plants in this group had not been recorded previously.

Tobacco crop irrigated one day before the occurrence of the frost was damaged as badly as that irrigated about a fortnight earlier.

Acknowledgement

I wish to take this opportunity of thanking most heartily, Dr B. P. Pal, Imperial Economic Botanist, for providing the necessary facilities in the compilation of the notes.

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STUDIES ON THE DISTRIBUTION OF DIFFERENT FORMS OF PHOSPHORUS IN SOME INDIAN SOILS

I. SURFACE DISTRIBUTION

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It is an established fact that majority of Indian soils are very poor in their contents of available phosphorus, although the total quantity of phosphorus in them is found to be quite high. Fixation or reversion of easily soluble phosphorus into unavailable forms is shown in an acute form in these soils, especially in the red ones. It is also believed that a good amount of the phosphorus of these soils exists as ferric phosphate in the concretionary nodules. It was therefore thought that a knowledge of the distribution of the different forms of phosphorus in these soils would throw an interesting light on their remarkable unavailability and power of fixation. Such a distribution study will reveal the nature of the chemical changes by which the phosphorus undergoes reversion and the ultimate forms in which it accumulates under different soil conditions. With this object in mind, a number of Indian soils has been fractionated with regard to their phosphorus by a method of fractionation originally proposed by Dean [1938] and subsequently modified by Ghani [1942]. Ghani's method, with some minor changes to suit local soils, has been adopted all through this work. The proposed fractionation aims at dividing the soil phosphorus into the following five groups :

(a) Soluble in $N/2$ acetic acid (non-apatitic calcium phosphates).

(b) Inorganic phosphorus soluble in $N/4$ sodium hydroxide (iron and aluminium phosphates).

(c) Organic phosphorus soluble in $N/4$ sodium hydroxide.

(d) Soluble in $2N$ sulphuric acid (apatites).

(e) Insoluble.

DESCRIPTION OF SOILS

The soils have been selected from various parts of India with a view to obtaining as wide a range of conditions as possible. The study was made first on the surface samples only and later on it was extended to the distribution of fractions down the profile. The samples have been collected mostly from arable lands in the experimental and demonstration farms of the respective localities. In the soils under investigation the pH ranges from 4·2 to 8·4 while the organic carbon varies from 0·226 to 3·097 per cent. The total phosphorus of the samples ranges from 62 mg. to 266 mg. P_2O_5 per 100 gm. of soil while the sesquioxides vary from 2·99 to 24·00 per cent. In choosing the soils attention has also been given to the variety of soil types, kinds of crops grown and nature of fertilization practised on them. A brief description of the soils together with the more important soil constituents having some direct bearing on the phosphorus problem are presented in Table I and the results of fractionation are shown in Table II.

TABLE I

Description of soils with important soil constituents

Soil No.	Locality	Depth	pH	Org. C. per cent	Fe_2O_3 per cent	Al_2O_3 per cent	Sesquioxides per cent	P_2O_5 per cent	Remarks
1	Sibsagar, Assam	0-6 in.	5·2	1·191	1·27	7·92	9·19	0·133	Paddy soil
2	Sabour, Bihar	,,	8·3	0·917	3·20	12·20	15·40	0·192	Do
3	Coimbatore I, Madras	,,	8·4	0·791	0·91	9·96	10·87	0·082	Taken from paddy breeding station unmanured for one year
4	Coimbatore II, Madras	,,	8·4	0·578	2·26	21·74	24·00	0·108	Unmanured for more than 15 years
5	Kanke, Bihar	,,	5·6	0·412	1·20	8·30	9·50	0·077	Paddy soil
6	Karimganj, Assam	,,	4·5	0·895	1·28	4·72	6·00	0·112	Do
7	Faridpur, Bengal	,,	6·1	1·345	0·98	10·27	11·25	0·151	Do

TABLE I—*contd.*

Soil No.	Locality	Depth	pH	Org. C. per cent	Fe_2O_3 per cent	Al_2O_3 per cent	Sesqui-oxides per cent	P_2O_5 per cent	Remarks
8	Bogra, Bengal . . .	0-6 in.	6·8	0·307	1·40	9·88	11·28	0·159	Paddy soil
9	Titabari, Assam . . .	„	4·7	0·785	1·87	10·64	12·51	0·114	Do
10	Tippera, Bengal . . .	„	5·2	1·240	1·04	8·56	9·60	0·101	Do
11	Merida (Dacca), Bengal .	„	5·7	1·726	0·96	20·34	21·30	0·101	Paddy soil. Bura paddy grown. Soil submerged under water for 6 months in the year
12	Rajshahi, Bengal . . .	„	7·9	0·875	1·95	14·06	16·01	0·176	Paddy soil
13	Berhampur, Bengal . .	„	6·7	1·193	1·04	8·34	9·38	0·259	Do
14	Barisal, Bengal . . .	„	6·6	1·062	2·16	10·90	13·06	0·148	Do
15	Jalpaiguri, Bengal . . .	„	5·4	1·541	3·12	14·12	17·24	0·198	Do
16	Jessore, Bengal . . .	„	7·3	0·962	1·20	7·54	8·74	0·266	Sugarcane soil manured with castor cake and bone
17	Siliguri, Assam . . .	„	5·8	3·097	1·15	1·84	2·99	0·133	Black soil
18	Midnapur, Bengal . . .	6-12 in.	7·0	0·417	0·65	9·45	10·10	0·145	Taken from saline area, low land
19	Guntur, Stanbhagurva, Madras	0-6 in.	6·4	0·438	2·09	6·46	8·55	0·062	Dark red loamy soil
20	Bankura I, Bengal . . .	„	5·0	0·369				0·079	High land soil, Aus paddy grown
21	Bankura II, Bengal . .	„	4·2	0·451				0·078	Low land soil, Aman paddy grown
22	Suri I, Bengal . . .	„	5·1	0·226				0·071	High land soil, Aus paddy grown
23	Suri II, Bengal . . .	„	5·2	0·635				0·068	Low land soil, Aman paddy grown
24	Jhargram, Bengal . . .	„	4·2	0·305				0·109	Low land soil, Aman paddy grown
25	Gaya, Bihar . . .	„	5·1	0·407				0·062	Paddy soil

TABLE II

Fractions of soil phosphorus expressed as mg. P_2O_5 per 100 gm. of soil

Soil	pH	Acetic acid-sol.	Alk. sol. inorg.	Org.	Sulphuric acid-sol.	Insoluble	Total
Sibsagar .	5·2	8·2	23·4	47·6	12·8	41·0	133·0
Sabour . .	8·3	53·0	44·0	49·3	16·0	29·7	192·0
Coimbatore I .	8·4	15·2	17·4	30·6	10·6	8·2	82·0
Coimbatore II	8·4	12·0	19·8	28·2	12·0	36·3	108·3
Kanke . .	5·6	2·2	19·8	18·6	6·4	30·0	77·0
Karimganj .	4·5	1·6	19·2	45·8	6·8	39·7	113·1
Faridpur .	6·1	24·4	32·0	41·6	4·0	48·9	150·9
Bogra . .	6·8	22·0	36·8	59·2	26·0	15·0	159·0
Titabari .	4·7	2·9	32·0	35·2	8·0	36·4	114·5
Tippera .	5·2	15·2	16·3	30·3	7·0	32·2	101·0
Merida . .	5·7	27·4	21·3	34·7	7·7	10·2	101·3
Rajshahi .	7·9	53·0	24·0	24·0	24·0	50·5	175·5
Berhampur .	6·7	136·0	25·0	43·8	19·6	34·9	259·3
Barisal . .	6·6	50·0	24·0	27·2	12·4	33·9	147·5
Jessore . .	7·3	116·0	29·3	37·9	56·0	26·6	265·8
Jalpaiguri .	5·4	10·0	28·2	91·8	22·0	45·7	197·7
Siliguri . .	5·8	6·0	26·6	98·7	17·6	–16·3	132·6
Midnapore .	7·0	50·0	20·0	26·8	28·5	20·2	145·5
Guntur . .	6·4	Trace	8·0	20·8	9·2	24·5	62·5
Bankura I .	5·0	Do	7·5	43·1	12·4	16·5	79·5
Bankura II .	4·2	Do	13·0	51·0	5·8	8·6	78·4
Suri I . .	5·1	Do	6·4	53·6	4·5	6·9	71·4
Suri II . .	5·2	Do	5·0	48·3	4·0	10·7	68·0
Jhargram .	4·2	2·4	9·0	27·0	3·6	67·0	109·1
Gaya . .	5·1	4·6	18·6	21·4	9·0	8·4	62·0

ACETIC ACID-SOLUBLE PHOSPHORUS

It will appear from Table II that acetic acid-soluble phosphorus is very small in the majority of the soils studied. In the acid soils over a pH range from 4·2 to 5·8, it is either nil or forms an insignificant part of the total soil phosphorus. As the reaction of the soil approaches the neutral point, greater amount of soil phosphorus is dissolved by this solvent. In the Berhampur and Jessore soils having a pH of 6·7 and 7·3 respectively, the fractions are outstandingly high, and amount to 136 and 116 mg. P_2O_5 per 100 gm. of soil. As the pH of the soil changes towards the alkaline side of the reaction the fraction shows a tendency to decrease. Thus in Rajshahi, Sabour and Coimbatore soils, the pH of which are 7·9, 8·3 and 8·4 respectively, the acetic acid-soluble phosphorus amounts to 53, 53 and 15 mg. P_2O_5 per 100 gm. of soil. Thus it seems that the availability of the soil phosphorus as determined by the acetic acid-soluble fraction is closely related to the pH of the soil. The relation of the available phosphorus with soil reaction is made clear from the trend of changes just described. Since the total phosphorus of the soils under study varies

within a very wide limit, it is to be expected that the correlation just considered would be much more real if the fractions are expressed as per cent of the total soil phosphorus. In Table III the fractions have been shown as per cent of the total phosphorus. As before in Berhampur and Jessore soils the highest percentages (52 and 44) of the soil phosphorus are present in the acetic acid-soluble form, while in the three alkaline soils (pH 7·9, 8·3 and 8·4) the quantity gradually diminishes from 30 per cent to about 19 per cent.

TABLE III

Fractions of soil phosphorus expressed as per cent of total P_2O_5

Soils	pH	Acetic acid-sol.	Alk. sol. inorg.	Org.	Sulphuric acid-sol.	Insoluble
Sibsagar .	5·2	6	18	36	10	31
Sabour .	8·3	28	23	26	8	15
Coimbatore I	8·4	19	21	37	13	10
Coimbatore II	8·4	11	18	26	11	34
Kanke .	5·6	3	26	24	8	39
Karimganj .	4·5	1	17	41	6	35
Faridpur .	6·1	16	21	28	3	32
Bogra .	6·8	14	23	38	16	9
Titabari .	4·7	2	28	31	7	32
Tippera .	5·2	15	16	30	7	32
Merida .	5·7	27	21	34	8	10
Rajshahi .	7·9	30	14	14	14	29
Berhampur	6·7	52	10	17	8	13
Barisal .	6·6	34	16	18	8	23
Jessore .	7·3	44	11	14	21	10
Jalpaiguri .	5·4	5	14	46	11	23
Siliguri .	5·8	5	20	74	13	..
Midnapur .	7·0	34	14	18	20	14
Guntur .	6·4	..	13	33	15	39
Bankura I .	5·0	..	9	54	15	21
Bankura II	4·2	..	17	65	7	11
Suri I. .	5·1	..	9	75	6	10
Suri II .	5·2	..	7	71	6	16
Jhargram .	4·2	2	8	25	3	62
Gaya .	5·1	7	30	34	14	14

It is thus evident that in acid soils available phosphorus is present in very small amounts, that under neutral and nearly neutral conditions the available phosphorus is at its highest and that under alkaline conditions comparatively small proportion of the soil phosphorus is in the available form.

The low availability of the phosphorus of acid soils is usually attributed to the fixation of the easily soluble phosphorus by the free oxides of iron and aluminium. Beater [1937] pointed out that within the pH range of most acid soils phosphate fixation is largely due to the formation of iron and aluminium phosphates or the more insoluble basic phosphates of these cations. Several workers — notably Roszmann [1927], Mattson [1931], Pugh and Dutoit [1936] and Ravikovitch [1938]—hold the view that, within certain ranges of reaction at least, phosphorus is adsorptively fixed on the surface of clay particles. Metzer [1940] however draws the conclusion that for acid soils under field conditions adsorption or chemical precipitation may account very largely for phosphate fixation and that adsorption is probably of small practical significance. Lately Chandler [1941] obtained results to show that the capacity of clay for adsorbing phosphorus was greatly reduced if it was freed from the free iron and aluminium oxide by a pretreatment and believed that in most acid soils fixation was due to the formation of insoluble iron and aluminium phosphates. As in the present work the iron and aluminium phosphates have been determined as definite fractions, it affords an excellent opportunity to test the point in question.

ALKALI-SOLUBLE INORGANIC PHOSPHORUS

This fraction which is mainly phosphates of iron and aluminium ranges from about 7 per cent to 30 per cent of the total phosphorus in the 25 soils studied (Table III). From Table II also it will appear that the values of this fraction expressed as mg. P_2O_5 per 100 gm. of soil vary from 5 to 44. It might have been expected that this fraction would predominate only in the acid soils but the results show that it is as high as 23 per cent in an alkaline soil having a pH of 8·3. The sesquioxide content of this soil was also found to be abnormally high. On the other hand, some acid soils are very low in this fraction. This is contrary to the popular view that in acid soils inorganic phosphorus accumulates mostly as iron and aluminium phosphates. Though, on an average, there is a tendency of the acid soils for having high amounts and of neutral soils low amounts of this fraction, the agreement does not hold well on the whole. Dean [1938] showed that the relationship between alkali-soluble inorganic phosphorus and pH was as such insignificant but became significant if corrections were made for the differences in carbon and clay content. By a reference to Tables II and III it will be seen that the organic phosphorus of the acid soils are very high. As the inorganic and organic phosphorus contents of the soils vary within very wide limits it is quite likely that if allowance is made for the differences in organic phosphorus, results may reveal their true significance. One way of doing this is to express the fraction as per cent of the total inorganic phosphorus of the soil.

It has actually been found that if the results are so expressed, its relation with pH becomes more apparent. This will be evident from Table IV. (In these correlation studies, Sabour and Coimbatore Soils having their pH above 8 have been excluded for the apparent anomalies they exhibit.

In spite of their alkaline reaction, iron and aluminium phosphates are comparatively high, while the apatite phosphate is relatively low in them. They contain high amounts of sesquioxides made up mostly of aluminium oxide. It may be presumed that if in a soil, even in a calcareous one, there is present considerably more aluminium than calcium, a considerable quantity of phosphorus has gone into combination with aluminium during the ages of weathering. Though lime may precipitate a part of the phosphorus as tricalcium phosphate and though carbonato-apatite or hydroxy-apatite may also be formed simultaneously, the extent of this reaction must be slower than what would have been the case if the former reaction were absent).

TABLE IV

Alkali-soluble inorganic P_2O_5 as per cent of the total inorganic P_2O_5

Soils	pH	Alk.-sol. inorg. P_2O_5	Total inorg. P_2O_5	Alk.-sol. inorg. P_2O_5 as percentage of the total inorg. P_2O_5
Sibsagar	5·2	23·4	85·4	27
Kanke	5·6	19·2	58·4	34
Karimganj	4·5	19·2	66·3	30
Faridpur	6·1	32·0	109·3	29
Bogra	6·8	36·8	99·8	37
Titabari	4·7	32·0	79·3	40
Tippera	5·2	16·3	70·7	23
Merida	5·7	21·3	66·5	32
Rajshahi	7·9	24·0	151·5	16
Berhampur	6·7	25·0	215·5	11
Barisal	6·6	24·0	120·3	20
Jessore	7·3	29·3	227·9	12
Jalpaiguri	5·4	28·2	105·9	27
Siliguri	5·8	26·6	33·9	78
Midnapur	7·0	20·0	118·7	17
Guntur	6·4	8·0	40·6	20
Bankura I	5·0	7·5	36·4	21
Bankura II	4·2	13·0	27·4	47
Suri I	5·1	6·4	17·8	36
Suri II	5·2	5·0	19·7	25
Jhargram	4·2	9·0	82·0	11
Gaya	5·1	18·6	30·6	60

It will be seen that iron and aluminium phosphates are relatively high in the acid soils and that they tend to decrease as the pH increases. This will explain the very low figures of acetic acid-soluble phosphorus found in acid soils. In the acid range available phosphorus increases with pH, whereas here we find that the amounts of iron and aluminium phosphates decrease with pH. On the other hand, neither of these fractions show any relation to the total sesquioxide content of the soils. These observations fit together to indicate that fixation in acid soils is mostly due to the formation of iron and aluminium phosphates by chemical interaction between the soluble phosphorus and hydrated oxides of iron and aluminium. As the pH of the soil increases the sesquioxides become less and less active, the amount of iron and aluminium phosphates formed progressively falls and as a result greater and greater quantity of phosphorus remains in the available form.

PHOSPHORUS SOLUBLE IN SULPHURIC ACID

It has been shown before [Ghani and Aleem, 1943] that by successive extraction with acetic acid and sodium hydroxide, most of the mono-,di- and tri-calcium phosphates, iron and aluminium phosphates would be removed and that the phosphorus subsequently dissolved by 2N sulphuric acid would represent the apatite phosphates of the soil. It will be seen from Tables II and III that in the soils under investigation this fraction is lower than the alkali-soluble inorganic fraction (iron and aluminium phosphates) except in the non-acid soils. On an average, less than 10 per cent of the total phosphorus comes under this category, though in the neutral soils it is much higher than the mean value. The highest amount—21 per cent—was found in a soil whose pH is 7·3 and which was fertilized with bone-meal. The lowest amount—3·0 per cent—was found in a soil (Jhargram) whose pH is 4·2—the lowest of the lot. In this respect it offers a contrast to the iron and aluminium phosphates which tend to fall off with increase in pH. The relation between pH and apatite phosphates reveals a general tendency of this fraction to increase with increase in pH.

It may be recalled that the acetic acid-soluble (i.e. available) phosphorus showed a tendency to decrease from neutral to alkaline reactions. The way the apatite phosphates vary with pH offers an explanation to that. It would seem that under neutral to alkaline conditions, specially in the presence of excess calcium carbonate, the soluble phosphorus of the soil would undergo precipitation into some form of apatites which are available to plants only with great difficulty. Basett [1917] has shown that in neutral or nearly neutral conditions much of the inorganic phosphorus is combined with calcium and probably occurs as hydroxy-apatite, this being the solid phase stable over a range extending from faintly acid to alkaline conditions. The works of Teakle [1928], Buehrer [1932], McGeorge [1935] and McGeorge and Breazeale [1932] all point to show that at equilibrium in the presence of calcium carbonate, in addition to the formation of tri-calcium phosphate, a very slightly soluble carbonato-apatite of the formula 3 $Ca_3(PO_4)_2$. $CaCO_3$ may be formed. The comparative unavailability of

phosphorus under alkaline conditions as observed here would thus appear to be due to the conversion of a part of the soluble phosphorus into very insoluble compounds of apatite type.

Organic phosphorus

The amount of organic phosphorus found in the soils differs within a very wide limit; it ranges from 14 per cent to about 75 per cent of the total soil phosphorus (Table III). The highest amounts are present in soils of high carbon content and high acidity. If the number of factors that are responsible for the accumulation of organic phosphorus in soils be taken into consideration, the wide range of variation found can be easily understood. The nature and amount of organic phosphates that are added to the soil in the form of crop residues and organic manures, its resistance towards microbial decomposition and its synthesis from the mineral phosphates will all play their part in deciding the extent of its ultimate accumulation in soil. The degree of biological decomposition or synthesis is largely governed by the abundance and activity of microflora which are again dependent on the reaction of the medium. The amount found at any time would therefore represent a dynamic equilibrium depending upon the soil conditions and its stability, like that of the soil organic matter as a whole, is to be regarded as relative rather than absolute.

The works of Auten [1922], Odynsky [1936], Schollenberger [1920] and Wrenshall and Dyer [1939] show that in the surface layers of many soils 30-85 per cent of the phosphorus is present in the organic form. By a reference to Tables II and III, it will be observed that in the four acids soils from Bankura and Suri on which *aus* and *aman* paddy have been continually grown for many years, the organic phosphorus is present in a very high proportion, some times as high as 75 per cent. The crop residues in the form of stubbles and straws that are generally left to rot in the soils are undoubtedly the cause for these high values. The high acidity and consequent lower microbiological activity together with the relative resistance of the phosphatic organic matter might have contributed to the high degree of accumulation of organic phosphorus found in them.

Organic phosphorus and soil reaction

Organic phosphorus decreases with increase in pH reaching a minimum at about the neutral point. Beyond that there is a tendency of the fraction to increase. The occurrence of much organic phosphorus under alkaline conditions may be due to less abundance of micro organisms in so far as they are affected by high alkalinity. That soil bacteria are much affected by alkaline reaction of the medium has been shown by Bear [1917] and Thornton [1922]. Their results show that bacterial numbers are small for low pH values; they rise suddenly between pH 6·8 and 7·0, and gradually fall at higher values.

All these suggest that the accumulation of organic phosphorus in soil is mainly a function of microbiological activities which would be highest in neutral soils or in other words, that organic phosphorus compounds are relatively stable under acid conditions. It also suggests that a part, at least, of the high quantity of available phosphorus found in neutral soils is derived from organic phosphorus through mineralization. The behaviour of organic phosphates in alkaline reaction offers an additional explanation (besides apatite formation) of the decreasing tendency of acetic acid-soluble phosphorus above the neutral point. It would thus seem that both decomposition of organic phosphorus and fixation of inorganic phosphorus are jointly responsible for the availability of soil phosphorus under different soil conditions.

Insoluble phosphorus

The phosphorus that still remains in the soil after the alternate acid and alkali treatment comes to a mean value of about 25 per cent of the total. This fraction must be a very resistant and inert type and of little value to plants. In Dean's work [1938], this was found to be the largest single fraction, the mean for 34 mineral soils was 43·2 per cent of the total phosphorus. It was further shown by him that over 50 years of fertilization at Rothamsted and Woburn did not produce any change in this fraction which should be taken as a proof of its inertness.

The pH of the soils bears no relation with this fraction; neither does the sesquioxides. Dean stated that the proportion of insoluble phosphorus decreased as the proportion of organic phosphorus and carbon increased but no explanation was given by him for this behaviour. On examination of Tables II and III it will be found that in the majority of soils, the organic phosphorus and insoluble phosphorus stands in the same relationship as observed by Dean [1938], that is, the insoluble phosphorus decreases as the organic phosphorus increases. The significance of this relation cannot be elucidated at the present state of our knowledge of the nature of the insoluble fraction. At the first sight it may merely mean its preponderance in mineral soils and its occurrence may depend on the nature of the parent material.

Availability of soil phosphorus

From the practical view point of availability, the above distribution study of the soil phosphorus

points, among other things, to the following conclusions :

(1) The availability of the soil phosphorus is mainly a function of the soil reaction.

(2) Unavailability of phosphorus under acid conditions is due to (a) fixation of easily soluble phosphorus in presence of active sesquioxides into insoluble phosphates of iron and aluminium and (b) accumulation of organic phosphorus due to lack of microbiological activity.

(3) Unavailability of phosphorus under alkaline conditions is due to (a) fixation of easily soluble phosphorus in presence of calcium carbonate into very insoluble compounds of apatite type and (b) lower rate of decomposition of organic phosphorus compounds due to lesser microbiological activity.

(4) High availability under neutral conditions is due to (a) absence of any of the two types of fixation mentioned above and (b) rapid mineralization of organic phosphorus through biological agencies.

In coming to the above generalization the acetic acid-soluble fraction has been taken to represent the available phosphorus of the soil, as the direct availability of other fractions, viz. iron and aluminium phosphates and organic phosphates is still held to be very doubtful. Attempts have of course been made from time to time to assess the agricultural value of the organic phosphates and the insoluble inorganic phosphates but the results, in most cases, are either undecisive or unsatisfactory.

Summary

The distribution of different forms of phosphorus in some Indian soils has been studied in detail and phosphate availability as influenced by soil conditions has been discussed in the light of known phosphorus fractions.

Acetic acid-soluble or available phosphorus is extremely small in the acid soils over a pH range of 4·2 to 5·8. Under neutral conditions it occurs in the highest proportion while as the reaction shifts towards alkalinity the fraction tends to decrease.

Iron and aluminium phosphates are relatively high in acid soils and tend to decrease as the pH increases.

On an average, less than 10 per cent of the total soil phosphorus is present in the apatite forms. In contrast to iron and aluminium phosphates, this fraction tends to increase with increase in pH.

The organic phosphorus occurs in the highest amounts under acid conditions and decreases with increase in pH reaching a minimum at nearly neutral reactions and then increases with increase in pH, suggesting that its accumulation in soil is mainly a function of microbiological activities.

The insoluble fraction comes to a mean value of 25 per cent of the total. It is related neither with pH nor with sesquioxide content. In the majority of soils, it, however, decreases as the organic phosphorus increases.

Unavailability of phosphorus under acid conditions is due to the formation of iron and aluminium phosphates and high accumulation of organic phosphorus. Under alkaline conditions it is due to the formation of insoluble apatites and lower rate of decomposition of organic phosphorus. High availability under neutral conditions is due to the absence of any fixation and rapid mineralization of organic phosphorus.

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WILT OF GRAM IN RELATION TO DATE OF SOWING

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(With Plate XIII)

It is known that soil-borne diseases of crops are sharply influenced by soil conditions, notably temperature and moisture. In certain experiments conducted at the Imperial Agricultural Research Institute during the season 1938-39 there was a suggestion that temperature played an important part in the development of gram (*Cicer arietinum* L.) wilt. During the same season it so happened that an experiment had been made by the Imperial Agriculturist at the farm at Delhi to determine the effect of different dates of sowing (which means, incidentally, different soil moistures and temperatures) on the growth and yield of gram. Advantage was taken of this opportunity to take notes on the incidence of wilt in the plots, and as the results obtained were interesting, the experiments have been repeated each year since then. It has thus at the time of writing (July 1942) completed its fourth season.

Procedure

The experiment was laid down in the form of a Latin square, with six replicates and six dates of sowing (September 23 and 30* and October 7, 14, 21 and 28). The size of each plot was 20 ft. × 14 ft. during the season 1938-39, 36 ft. × 21 ft. in 1939-40 and 35 ft. × 20 ft. in 1940-41 and 1941-42 and a border of gram 2 ft. wide was allowed on all sides. The variety of gram sown was IP 25.

The plots were irrigated just prior to sowing, but received no further irrigation.

Gram seedlings often wilt while they are very small, and in these cases it is necessary to observe them before they wither up and are completely lost. Furthermore, the plants tiller profusely, and a stage is soon reached when individual plants cannot be distinguished. In order to overcome these difficulties, the following procedure was adopted: A fixed number of rows (two rows per plot during the first two years and five rows thereafter) was taken at random and marked. Seedlings in each row were counted as soon as emergence of the seedlings through the soil was complete. This germination figure was the basis for calculation of wilt percentage. As soon as wilting was observed, all the wilted plants were removed from the marked rows and counted. This was repeated at convenient intervals, usually every three weeks to one month, so that there was no possibility of missing plants which dried and withered up. At the end of the season it was possible to record the number of wilted plants in each row as a percentage of the germinated seedlings.

The yields of the plots were taken at maturity. As wilted gram plants produce no seed, their removal did not influence the results.

Results

The percentages of plants which wilted and the yields of gram seed obtained for each treatment are given in Table I. Due to a misunderstanding the plots sown on 23 September 1941, which were almost destroyed by wilt by the middle of November, were ploughed up, so that final figures were lost. Practically no plants remained alive in this plot when it was ploughed. The 1942 crop was lost due to a severe hail storm; the yield, however, promised to be poor even in the best plots owing to severe drought and consequent shrivelling of grain. The effect of date of sowing on stand is clearly indicated in Plate XIII, which shows the condition of the plots on 3 January 1942.

Conclusions

The evidence is strong that delaying sowing until the middle of October or later substantially reduces the incidence of gram wilt in a year when this disease is severe. There is a corresponding increase in yield until the middle of October, after which the yield tends to fall even though reduction in wilt incidence continues. The results in the year 1938-39 are curious in that late sowing markedly increased the yield despite the fact that it was not a year of severe wilt. Throughout the experiment yields were rather poor due to the fact that the experiment was conducted during a series of extremely dry years. The rainfall recorded during the period September 15 to March 31 was 2·6, 6·8, 4·2 and 2·8 inches respectively for the four successive years of the experiment.

As to the applicability of results to practical conditions, it has to be remembered that in

*October 1 in the season 1941-42

north-western India, where wilt is important, the crop is sown on residual moisture from the monsoon, and cultivators are not inclined to delay sowing for fear of failure to germinate if there are no showers of rain in September. The question of conserving or supplying moisture, therefore, arises.

There is also some evidence of a relationship between gram wilt and subsoil moisture, a point which will be brought out in a separate note.

TABLE I

Influence of sowing date on development of wilt and on yield of gram during the four cropping seasons, 1938-42

Date of sowing	1938-39		1939-40		1940-41		1941-42	
	Percentage of wilt	Yield (lb. per acre)	Percentage of wilt	Yield (lb. per acre)	Percentage of wilt	Yield (lb. per acre)	Percentage of wilt	Yield (lb. per acre)
23 September	3·7	265	1·5	1298	20·0	931	62·9*	Crop destroyed by hail
30 September	11·5	814	1·5	1470	12·6	1036	64·5	...
7 October	2·6	1087	1·6	1484	10·3	1092	41·0	...
14 October	1·8	1354	2·8	1456	3·5	1304	22·3	...
21 October	0·1	1315	0·9	1652	1·1	1260	10·8	...
28 October	0·0	1243	1·5	1518	1·6	1275	5·0	...

* Observations on the plots sown on 23 September 1941 were discontinued after 6 November

The results brought forward here are not intended to suggest that late sowing of gram should be recommended as a control measure for wilt under a cultivator's conditions where he cannot rely on moisture for germinating the crop. It is evident, however, that the method, if it can be adopted, offers distinct promise and deserves trial in various places in north-western India. Means of solving the question of moisture for germination may suggest themselves to various workers in different forms according to local conditions, and it is hoped that date-of-sowing experiments with this crop will be laid down in various districts where gram wilt is severe.

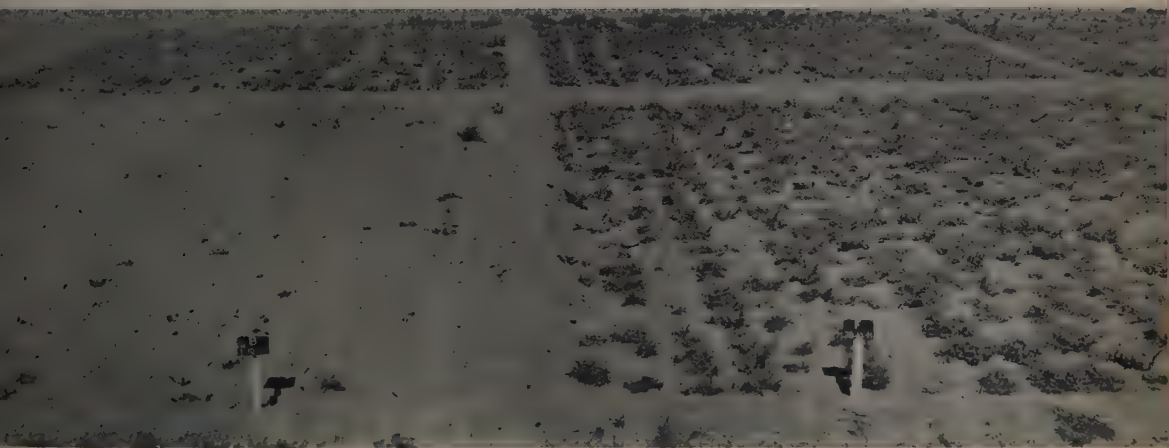
SUMMARY

In experiments conducted at the Imperial Agricultural Research Institute farm at Delhi over four seasons gram (*Cicer arietinum* L.) was sown at weekly intervals commencing September 23. Wilt decreased in intensity as sowing was delayed and the yield of grain correspondingly increased until at least the middle of October, after which there tended to be a slight decline.

ACKNOWLEDGEMENT

The authors are grateful to the Imperial Agriculturist for affording facilities for making observations in these experiments.

D B



B F

Effect of date of sowing of gram (*Cicer arietinum* L.) on the stand of the crop on 3 January 1942

B Plot sown on 1 October 1941

D Plot sown on 14 October 1941

F Plot sown on 28 October 1941

BIOCHEMICAL STUDIES IN THE GROWTH AND RIPENING OF THE ALPHONSE MANGO

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(With four text-figures)

The mango is a tropical fruit and thrives well in both tropical and subtropical regions. Yet it is only in India that the best varieties of mango are produced. Recently its cultivation has been attempted in other countries but has not been wholly successful. The superior quality of the Indian fruit is still maintained. Certain Indian varieties when planted in other countries did not bear fruits of the same good quality [Popenoe, 1938].

According to the old Vedic literature the mango appears to be indigenous to India [Burns and Prayag, 1920]. Numerous varieties of the mango, both cultivated and wild, are spread all over India. Commercially, however, only a few of them are important, and the Alphonse is considered to be one of the best among them. This variety is extensively cultivated in the Deccan, the southern part of Gujarat and the Konkan. It is highly esteemed by consumers both in India and abroad. Another important feature of this variety is its keeping quality which makes it the most suitable fruit for both storage and transport. Burns and Prayag [1920] have described the fruit of the Alphonse mango as under : length, 9 cm. ; breadth, 6 cm.; thickness, 4·5 cm. ; taste, very luscious ; smell, fragrant ; flesh, reddish in the middle and pale yellow on the outer side ; general appearance, left shoulder higher than the right and thin skin closely attached to the flesh.

Work on the physiological changes during growth and ripening of the mango fruit is very scanty. It is still more so in the case of the Alphonse mango. Banerjee, Karmarkar and Row [1934] have reported studies on the storage of mango. According to them the fruit ripens on the fifth day after plucking and that putrefaction sets in after 10 days. The acidity of the fruit is considerably reduced during ripening while the sugar content rapidly increases. Singh, Seshagiri and Gupta [1937] have studied the ontogenetic drift in the physiology and chemistry of two varieties of mango. They observed two maxima in the respiratory curve of the fruit. The first was during the early stages of growth and the second at the climacteric. The nitrogen content of the fruit showed fluctuations similar to the respiratory index. The reducing sugars exhibited two maxima corresponding to the two maxima in the respiratory activity, whereas sucrose showed a continuous rise. The pH value of the fruit sap changed in a direction opposite to that of total acidity and reached a maximum value at the climacteric. Wardlaw and Leonard [1936, 2] studied the changes during the storage of West Indies mangoes. They observed an increase in acidity during the early stages of growth which decreased slowly up to maturity. The decline in acidity during ripening was very rapid. They also observed a marked gradient of increasing acidity from skin to stone. This was, however, found to decrease with ripening. Cheema, Karmarkar and Joshi [1939] have reported their investigations on the cold storage of mango. They found that the Alphonse variety was the best keeper. The different climatic and soil conditions under which it grows in the Bombay province made no difference to its ' storage life ', though the fruit from Ratnagiri remained green for a longer period as compared with the fruits from other localities. The changes in the chemical composition of the Alphonse fruit stored at different temperatures showed that the fruit ripened at 68° or 60°F. contained more total sugars than that ripened at room temperature. The sugars were rapidly consumed when the fruit became over-ripe.

The same authors also studied the chemical composition of the green and ripe fruit of different varieties of mango. They observed a correlation between the acid content of green fruit and the length of the ' storage life ', the latter being short in the case of fruit with low acidity and long in the case of fruit with high acidity. No such relation was found to exist between the total nitrogen content and the keeping quality of the fruit.

Karmarkar and Joshi [1941] studied the respiration of Alphonse mango under different storage conditions. They found that the respiratory activity of the green fruit (B stage of maturity) increased during the first four or five days after which it decreased as the fruit ripened. The decline in the rate of respiration during ripening was accompanied by an increase in the amount of total sugars and a loss in acidity. It was inferred, therefore, that the rate of respiration was not influenced by increase in the concentration of

sugars and that it decreased due to the depletion of acids present in the fruit.

In the present investigation the physical and chemical changes and the respiratory activity associated with the development and ripening of the Alphonse variety have been studied. The effect of plucking the fruit at different stages of growth on the quality of the final product and its respiratory activity during ripening has also been investigated.

Material and methods

The fruits for these investigations were kindly supplied by the Horticulturist to the Government of Bombay, Poona. Two trees of the Alphonse variety were reserved for the purpose. The fruits were bagged when they were a month old. Samples were taken at intervals of 15 days from this date onward. For the first two samples, when there was a great variation in the size of the fruit 20 fruits of an average size were taken at each sampling. Later the size of the fruit became more uniform and therefore only 15 fruits were removed each time. When the fruits became mature a sample of 50 fruits was taken for ripening. They were wiped clean and kept in grass for ripening. This is the usual commercial practice. By the eighth day the fruits became fully ripe with an attractive golden colour, and acquired the characteristic flavour and taste. The temperature of the *adhi* (i.e. the grass bed in which the fruits were kept for ripening) ranged from 30° to 32°C. while the temperature of the room varied during this period from 26° to 27°C. On the eighth day the fruits were removed from the *adhi* and kept at room temperature in the open. During this period samples were taken at more frequent intervals. Each sample consisted of three fruits of the same degree of ripening as judged from the feel, colour and flavour.

At each stage, the fruits were wiped dry and then weighed individually. Two fruits of average size were taken for the respiration measurements, the rest being used for chemical analysis. Peel, pulp and stone-kernel were separately analysed.

The methods of analysis employed were the same as those reported in an earlier investigation [Leley, Narayana and Daji, 1940]. Moisture was determined in the fresh material by treating it first with calcium carbonate and 95 per cent alcohol and then drying for four hours at a low temperature on the top of the water oven and finally for one hour inside it. Nitrogen was estimated by the Kjeldahl method. *p*H determinations were made on the expressed juice using the quinhydrone electrode. For sugar, the fresh material was extracted with 80 per cent alcohol, the extract freed from alcohol, clarified with neutral lead acetate and sugar determined by the Bertrand method. Glucose and fructose in the extract were separately determined by the iodimetric titration of Willstatter. In the residue after alcohol extraction, starch was estimated by the taka diastase method and the residue from this was used for the determination of the acid hydrolyzable matter. The respiratory activity was determined by the flow method using the apparatus described in the previous paper. The results are expressed as percentages of the fresh weight. During ripening when the moisture content of the fruit suffers rapid fluctuations, the results when referred to the fresh weight on the day of analysis fail to bring out the actual trend of changes [Archbold, 1928]. The results of analyses during ripening are, therefore, expressed on the fresh weight of the fruit on the day when it was put in the *adhi*.

Results and discussion

Fresh weight. Table I shows the average weight of the fruit at the various stages of growth. The results are plotted graphically in Fig. 1.

Table I

Fresh weight and its rate of increase

(Average of ten fruits)

Days of growth	30	45	60	90
Weight (in gm.)	50·72	111·30	194·20	259·90
Rate of increase of weight per day (in gm.).	1·69	4·04	5·53	2·20

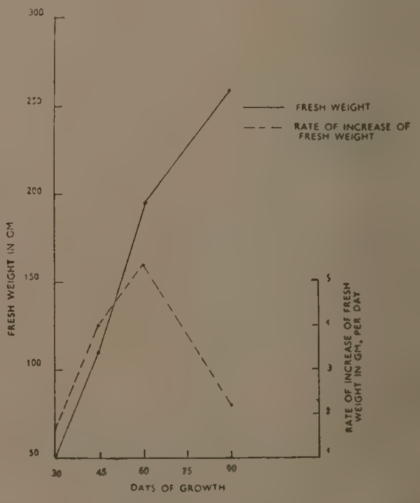

Fig. 1. Fresh weight and rate of increase of fresh weight of the Alphonse mango

The average weight of the mango fruit increases very rapidly up to two months. The maximum weight is, however, reached at the end of three months. At this time the fruit seems to have matured. It was externally indicated by the raising of the shoulders off the stem-end and the appearance of a yellow flush on the skin. The fresh weight of apples was also found by Archbold [1928] to increase up to maturity.

The rate of increase of weight goes on rising gradually up to the second month of growth. Thereafter it declines sharply. When the fruit is about to mature the growth rate assumes a very low value. Singh, *et al.* [1937] observed similar changes in the growth rate of the Krishnabhog variety of mango. In the case of the Langra mango, however, they found that the growth rate increased during the first month and then fell continuously up to maturity. The changes in the growth rate of banana are very similar to those of the Alphonse mango [Leley, *et al.* 1940].

Dry matter. The change in the dry matter content of the various parts of the fruit are shown in Table II.

TABLE II

Dry matter content of peel, pulp and stone-kernel

(Expressed as per cent on fresh weight of each part)

Days of growth	Pulp	Peel	Stone-kernel
30	11·40	23·90	17·85
45	13·02	20·73	..
60	16·61	..	41·25
75	21·14	27·42	56·32
90	22·24	28·89	61·30
Removed from tree and placed in *adhi*			
92	21·80	..	..
95	22·31	30·86	..
98	23·48	..	..
101	20·16	31·17	61·62
105	19·24	..	..
109	16·40	..	..
Deterioration set in			

The rise in dry matter in the stone-kernel is comparatively more rapid than in either pulp or peel. The maximum concentration of dry matter is reached in all the three parts of the fruit when it is mature. At maturity the stone-kernel contains only 38·70 per cent moisture. The drying up of the seed is a characteristic of maturity observed in other fruits also [Wardlaw and Leonard, 1935].

Coming now to the ripening period the changes in the dry matter are not very marked considering the great transformations taking place in the fruit. On the eleventh day of ripening (101st day) the dry matter of pulp begins to decrease. The fall continues to the end of the ripening period. This loss in dry matter is obviously due to the increase in the water content of the pulp. A similar increase in the water content of the banana pulp during the later stages of ripening has also been observed [Leley, *et al.* 1940]. There it was attributed to the transfer of moisture from the peel to the pulp. A similar transfer of moisture from peel to pulp is also likely in the case of the mango as during the same period the peel has lost a considerable amount of water.

Nitrogen. Table III shows the nitrogen content of pulp, peel and stone-kernel of the mango fruit.

TABLE III

Nitrogen content of pulp, peel and stone-kernel

Days of growth	Pulp	Peel	Stone-kernel	Stone-kernel
	Per cent on fresh weight			Per cent on dry matter
30	0·09	0·23	0·14	0·78
45	0·07	0·18	..	..
60	0·09	..	0·40	0·97
75	0·11	0·16	..	..
90	0·13	0·19	0·68	1·11
Removed from tree and placed in *adhi*				
101	0·15	0·16	0·67	1·09

The nitrogen content of peel is comparatively high in the beginning. During the development of the fruit, however, it gradually diminishes and assumes a constant value. In the pulp the nitrogen percentage is continuously increasing at a very slow rate. In the stone-kernel, however, the percentage of nitrogen increases very rapidly. At the termination of growth it is nearly five times that at the commencement. This rapid increase is, however, only apparent and is due to the loss of moisture from the seed during the maturation of the fruit. When the figures are referred to the dry matter of the seed (Table III, column 5), the increase of the nitrogen percentage is gradual. During ripening in the *adhi* the changes in the nitrogen content of the different parts of the fruit are not very significant. Singh, *et al.* [1937] studied the nitrogen content of the whole mango fruit during development and found it to increase to a peak value at the termination of the first two months of growth and then to decrease continuously. No such peak is observed when the nitrogen content of the three parts of the fruit is determined separately.

Acidity and p*H*. The acidity in the three parts of the fruit varies considerably. The pulp is nearly twice as acidic as either peel or stone-kernel during growth (Table IV).

TABLE IV

Acidity of pulp, peel and stone-kernel and pH of pulp

(Acidity expressed as gm. KOH per 100 gm. of fresh material)

Days of growth	Pulp acidity	pH of pulp	Peel acidity	Stone-kernel acidity
30	3·42	2·69	1·93	..
45	3·61	2·48	1·39	..
60	3·37	..	..	1·80
75	2·61	2·76	1·08	1·32
90	2·37	2·99	1·02	1·14
Removed from tree and placed in *adhi*				
92	1·63	3·17	..	..
95	0·72	3·64	..	..
98	0·23	4·76	..	..
102	0·20	5·22	0·81	1·20
105	0·18	5·30	..	..
109	0·35	..	..	..
Deterioration set in				

The acidity of the peel continuously diminishes right from the beginning and assumes a comparatively steady value when the fruit matures. During the ripening period it is further reduced to a still lower value.

The stone-kernel is slightly more acidic than the peel. Its acidity also shows a decline during devlopment. But contrary to the peel its acidity increases when the ripening sets in.

The changes in the acidity of the pulp are more pronounced than and somewhat different from the other two portions of the fruit. There is slight increase in the acidity up to the first 45 days and thereafter it decreases gradually throughout the period of development. The onset of senescence is prominently marked by a rapid fall in acidity of the pulp. During the first eight days, the actual period of ripening, the concentration of acids falls from 2·37 to 0·23 per cent. Later this rapid rate of fall is arrested and the acidity remains constant over a week more till deterioration starts. Fig. 2 shows the acidity and *p*H of the pulp. The curve for the *p*H is exactly converse of the acidity curve. This shows that the buffering capacity of the pulp is rather of a low order and remains unaltered throughout the period of growth and ripening.

Singh, *et al.* [1937] have recorded a similar trend of changes in acidity and *p*H of two other varieties of mango. Wardlaw and Leonard [1936, 2] found in a number of West Indies mangoes that the acidity decreased considerably during the short period of ripening.

Sugars and starch in pulp. The changes in the different forms of carbohydrates constitute the main activity of the fruit during development and ripening. Table V shows the sugar and starch contents of the pulp at the different stages of growth and ripening.

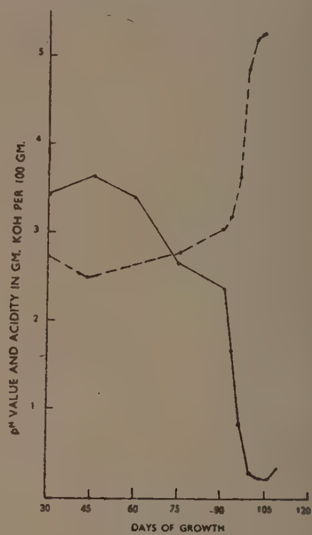

FIG. 2. Acidity and *p*H of pulp

TABLE V

Sugar and starch content of pulp

(Expressed as per cent on fresh weight)

Days of growth	Starch	Total sugars	Non-reducing sugars	Reducing sugars	Glucose	Fructose	Total fructose / Total glucose
30	1·13	2·68	0·33	2·36	1·36	0·95	0·73
45	4·35	..	..	..	..	..	..
60	6·02	5·01	3·95	1·06	0·68	0·38	0·88
75	12·05	5·87	4·52	1·35	0·80	0·59	0·93
90	13·79	6·81	5·75	1·06	0·63	0·43	0·94
Removed from tree and placed in *adhi*							
92	8·21	9·72	4·43	5·29	2·39	2·90	1·11
95	1·46	15·16	9·24	5·92	3·05	2·88	0·98
98	0·34	16·58	13·98	2·60	2·19	0·41	0·81
101	0·33	16·76	14·17	2·59	1·47	1·11	0·95
105	0·30	16·62	13·89	2·73	1·07	1·65	1·07
109	0·25	12·82	0·56	12·26	6·88	5·38	0·79
Deterioration set in							

During growth total sugars increase continuously from the beginning ; the rate of increase, however, slightly slackens during the last month of growth. Reducing sugars constitute almost the whole of the total sugars at the earlier stages of growth.

Gradually they decrease and reach a low concentration by the end of the second month. Non-reducing sugars which are low at the commencement of the growth assume an increasing gradient during the second month. This results in their concentration becoming nearly four times that of reducing sugars on the 60th day. This increase is continued to the end of growth. Starch which is at a very low concentration at the beginning gradually begins to increase during the first two months. Then there is a rapid rise from the 60th to the 75th day. The rate of starch accumulation is very low during the last fortnight.

The main points to be noted are the uniformly low concentration of reducing sugars, both glucose and fructose, throughout the growing period of the fruit. During the same period starch and non-reducing sugars increase rapidly. A large part of the glucose brought into the fruit appears to be stored as starch while only a small quantity is converted into sucrose. Lower concentration of fructose during the growing period seems to be a characteristic of the mango fruit. In the case of apples, however, along with the increase of the non-reducing sugars and starch there is a simultaneous and much larger increase in the concentration of fructose [Archbold, 1932 and Evans, 1928]. The explanation of this peculiarity of low concentration of fructose in the mango can be sought in the hypothesis put forward by Kidd [1935] to explain the mechanism of respiration in apples. According to this hypothesis, the glucose that is brought into the fruit cell is first condensed to starch in the cytoplasm while that which proceeds further to the interface between the cytoplasm and the vacuole is transformed into *gamma* fructose. A part of this active fructose is oxidized in respiration and the remaining is condensed with glucose. The sucrose so formed slips down into the vacuole where it is stored. If, however, enough free glucose is not available the active modification of fructose is again transformed and stored up as normal fructose. Kidd [1935] presents this process graphically as follows :

Glucose→*gamma* fructose
→Respired
→Condensed with glucose
→Converted to normal fructose

In apples, the accumulation of fructose is attributed to the scarcity of glucose. In the case of the mango, however, the low concentration of fructose may be due to the abundance of glucose. The balance of active fructose that remains after respiring is condensed with the abundantly available glucose to form sucrose. The low concentration of fructose and the large quantities of sucrose in the fruit are thus explained. Yet at all stages of growth, both free fructose and free glucose are present though in very small amounts. These may be the critical minimum concentrations of these sugars and only when they are exceeded does condensation into sucrose take place.

During the short period of ripening, the changes in concentrations of starch and sugars are very rapid. Almost all the starch is hydrolyzed in the first eight days and the total and non-reducing sugars reach the maximum concentrations at which they are maintained for a week more. Concurrent with the hydrolysis of starch the reducing sugars show a rapid rise up to the 95th day but soon fall to a low value by the 98th day. This is because the sucrose synthetic activity is not keeping pace with the rapid production of reducing sugars from starch. After the 95th day the latter slows down, but the sucrose synthetic activity continues for another three to four days and draws on the reducing sugars. This explains the sudden drop in the reducing sugars on the 98th day. After this, the sucrose synthesis ceases and the reducing sugars, therefore, remain constant during the next week.

Glucose and fructose naturally follow the same trend as the total reducing sugars. There is first a sudden increase in both the sugars and later by the 98th day they begin to fall. The fall in fructose concentration, however, is more marked than that in glucose. This is because all the fructose formed is utilized in the formation of sucrose. But during the next week after the 98th day, the fructose for the first time begins to accumulate and the glucose concentration begins to diminish. This is because glucose continues to be converted to *gamma* fructose. Some of it is oxidized during respiration. The balance is converted into normal fructose and stored in the fruit as there is no more supply of glucose and hence the sucrose synthetic activity ceases. Thus Kidd's hypothesis completely explains the changes in the various sugars in the pulp of the Alphonse mango. Similar to the apple, fructose accumulation proceeds in mango only when the supply of glucose is inadequate during the latter stages of ripening.

Evans [1928] has calculated the ratio of total fructose (free fructose + half sucrose) to total glucose (free glucose and half sucrose) in apples and has found it to be constant. The same is true of the Alphonse mango also as can be seen from Table V (column 8).

During the post-ripening period, after the 105th day the fruit begins to show signs of deterioration. Almost the whole of the sucrose gets hydrolyzed and the fruit contains only reducing sugars

Other carbohydrates in pulp. The alcohol-insoluble matter contains, in addition to starch, crude cellulose (cell-wall material) and cell-wall incrustations like pectins, hemicelluloses, etc. These latter substances on hydrolysis with dilute acids yield reducing sugars, which serve as a measure of these constituents. Table VI shows the percentages of these substances in the pulp at the different stages of growth and ripening.

TABLE VI

Alcohol-insoluble matter (other than starch)

(Expressed as per cent on fresh weight)

Days of growth	Alcohol-insoluble matter other than starch	Acid-hydrolyzable matter (as glucose)	Crude cellulose (by difference)
30	2·74	0·79	1·98
45	2·51	0·42	2·08
60	4·19	1·10	3·08
75	2·89	1·24	1·65
90	2·29	0·68	1·62
Removed from tree and placed in *adhi*			
92	1·99	0·39	1·60
95	1·97	0·29	1·69
98	1·74	0·17	1·56
101	2·11	0·21	1·90
105	2·14	0·25	1·88
109	2·68	0·32	2·36
Deterioration set in			

The gradual rise in the crude cellulose content during the early stages of growth, even in the face of the rapidly accumulating other carbohydrates, seems to point at the cell-division and cell-enlargement activities in the fruit. To strengthen the cellular structure, incrusting material is also deposited on the cell-walls during this period. At the end of two to two-and-a-half months these juvenile activities cease. No more crude cellulose is now being formed which explains the drop in the crude cellulose content from the 75th day onward.

The fall in the acid-hydrolyzable matter commences when the fruit has finished the storage of starch and is preparing for maturation. This fall is to be attributed to the hydrolysis of the incrusting substances in the fruit. It is also externally indicated by the softening of the fruit and the flesh becoming pulpy. This finding supports the view expressed by Murneek [1929] that the hemicelluloses form important reserve carbohydrates in plants. Widdowson [1932], however, did not find any fall in the hemicellulose and pectin contents of developing apples.

Sugars in peel and stone-kernel. In both these parts of the mango fruit the total sugar content is higher than in the pulp at the beginning of the growth ; thereafter it gradually decreases up to maturity (Table VII). When the fruit is ripe, the total sugars again increase in both peel and stone-kernel. The increase is more marked in peel than in stone-kernel.

In peel the reducing sugars form the major part of the total sugars and hence the changes in the reducing sugars during growth and ripening closely correspond to those in the total sugars.

In stone-kernel both reducing and non-reducing sugars are present at the various stages of development in more or less equal amounts.

TABLE VII

Sugars in peel and stone-kernel

(Expressed as per cent on fresh weight)

Days of growth	Peel			Stone-kernel		
	Reducing sugars	Non-reducing sugars	Total sugars	Reducing sugars	Non-reducing sugars	Total sugars
30	4·18	0·25	4·44	..	..	..
60	..	..	..	2·75	2·33	5·08
75	2·12	0·47	2·59	1·17	1·37	2·53
90	2·14	0·21	2·36	0·86	1·16	2·02
Removed from tree and placed in *adhi*						
101	5·12	2·30	7·42	1·45	1·92	3·36

Respiration. The respiratory activity of the Alphonse mango was followed by the flow method as described by the authors in their paper on banana [Leley, *et al.* 1940]. Fruits were removed from the tree after 30, 45, 60, 75 and 90 days of growth and their respiratory activity immediately determined. In addition, these fruits of different maturities were allowed to ripen in the *adhi* and their respiratory activities followed every day until the samples showed signs of deterioration. The results are given in Table VIII and graphically presented in Fig. 3. In drawing Fig. 3 the rates of respiration of the fruits on the day of removal of each individual sample from the tree have been joined up with those of the 90-day sample that was subsequently allowed to ripen in the *adhi*.

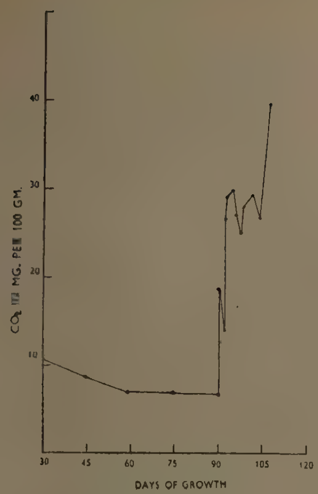

Fig 3. Respiratory activity of the Alphonse mango

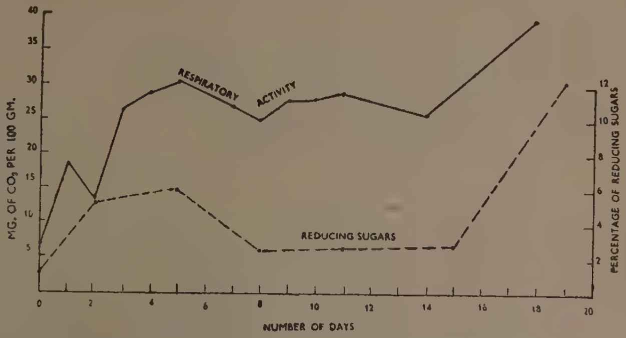

Fig. 4. Respiratory activity and reducing sugar content of Alphonse mango during ripening

Table VIII

Respiratory activity of the Alphonse mango removed from tree at different stages of growth

(Expressed as mg. CO_2 per 100 gm., fresh weight of fruit per hour)

Days after removal from tree	Days of growth				
	30	45	60	75	90
0	10·59	8·68	6·89	6·58	6·63
1	13·13	5·50	5·04	9·68	18·82
2	9·79	8·88	10·58	8·16	13·42
3	9·46	..	9·91	9·96	26·63
4	9·80	12·63	14·04	17·93	29·08
5	..	12·81	24·49	..	30·41
6	8·57	16·70	34·44	..	..
7	10·28	..	31·63	27·81	27·14
8	..	..	31·71	27·77	24·98
9	..	..	..	26·89	28·09
10	..	..	..	..	28·29
11	..	..	..	..	29·20
14	..	..	..	..	26·75
18	..	..	..	..	39·50

It will be noticed that the rate of respiration gradually declines during the first two months of growth and is practically constant in the third month. The rate of respiration of the mature fruit of 90 days growth is about two-thirds that at the beginning.

With the commencement of ripening, the rate of respiration suddenly increases to a high value in about six days. This value is nearly five times the rate of respiration of the fruit at maturity. This climacteric peak value is more or less maintained for a week more after which there is again a second rise. At this stage the fruit shows signs of deterioration. The climacteric peak values of respiration of other fruits during ripening also are considerably greater than the values at maturity [Kidd and West, 1930; Wardlaw and Leonard 1936, 1]. The respiratory curves of two other varieties of mango studied by Singh, *et al.* [1937] are in general similar to that of the Alphonse variety. But the climacteric rise in respiratory activity of those varieties is not so distinct and characteristic as is found in the Alphonse variety.

As sugars are the chief respirable material in the fruit the respiratory activity shows a close relation to the reducing sugar content of the pulp. The curves for reducing sugar and respiratory activity during ripening are almost parallel (Fig. 4). The vigorous hydrolysis of the starch commences on the 90th day which results in an increase of the reducing sugar content of pulp from 1·05 to 5·28 per cent on the 92nd day. There is thus plenty of available substrate for being respired and the rate of respiration increases with great intensity during this period and reaches the climacteric peak value on the 95th day. After this both the respiratory activity and the reducing sugars remain more or less steady till the fruit begins to deteriorate (105th day). At this stage the reducing sugars suddenly increase and consequently the rate of respiration rises sharply.

Respiratory activity and picking maturity. The effect of picking the mango fruit at different stages of maturity on the senescent life of the fruit can be clearly seen in the respiratory activities of the fruits on keeping for ripening (Table VIII). Fruits of 30 and 45 days maturity do not show any signs of ripening at all. After a few days the fruits shrivelled, became black and dried.

In the case of fruits of 60, 75 and 90 days maturity, there are clear outward indications of ripening. A golden yellow colour is developed and the fruits possess a sweet flavour and taste. There is also a definite and sharp climacteric rise in the rate of respiration. However, the period which must elapse after picking before the commencement of the climacteric rise gets shorter and shorter with advance in maturity of the fruits. Thus the climacteric rise in the rate of respiration starts after four, three and one day after picking in the fruits of 60, 75 and 90 days maturity respectively. On the other hand, the time required to reach the peak value from the start of the climacteric rise increases with age. Fruits of 60, 75 and 90 days maturity require three, four and five days respectively to reach the peak value. Thus in younger fruit, the climacteric is delayed, but once it starts it is very rapid. In mature fruit, on the other hand, the climacteric rise begins immediately the fruit is picked from the tree, but the rise towards the peak value is more gradual.

The chemical analyses of the ripe fruits which were picked after 60, 75 and 90 days of maturity are given in Table IX.

TABLE IX

Chemical analyses of fruits ripened after removing from tree at different stage of growth

(Expressed as per cent on fresh weight)

Growth in days	Dry matter	Acidity (gm. KOH)	Total sugars	Non-reducing sugars	Reducing sugars	Alcohol insoluble matter
60	15·15	0·39	9·90	5·90	4·01	2·51
75	19·39	0·19	14·38	11·46	2·93	2·44
90	23·48	0·23	16·58	13·98	2·60	2·07

It will be seen that the main differences in composition are the higher dry matter, total sugars and non-reducing sugars in the fruits ripened after picking at advanced maturity. This is mainly due to the starch content of the fruit at the time of picking. A reference to Table V shows that the fruits of 60 days maturity contain a much less amount of starch than those of more advanced maturity. Consequently the quality of the fruit ripened after 60 days of growth was poor and the taste was flat. Its acidity and reducing sugars content are, however, both higher than those of the other two samples. The starch contents at the time of picking of fruits of 75 and 90 days maturity were nearly the same. Hence the composition of these fruits on ripening do not materially differ and both possess the same taste and flavour. Thus the fruits picked a fortnight earlier ripen to the same quality as the more mature fruits of 90 days.

CONCLUSIONS

The life of the Alphonse mango is about 105 days. It requires 90 days to mature on the plant. Then it is put in a grass bed to ripen. This takes another eight or ten days. In the ripe condition the fruit can be preserved for about a week more after which there is functional breakdown of the fruit. From the foregoing study, the life of the Alphonse mango may be broadly divided into three phases: 1. period of adolescence (first 60 days); 2. period of maturation (next 30 days); and 3. period of senescence (last 15 days). The characteristics of each of these phases may now be briefly discussed.

Adolescence. During this period the percentage of crude cellulose (cell-wall material) steadily increases and reaches the maximum value at the termination of this phase. This indicates that the cell-division and cell-enlargement activities of the fruit cease and the fruit has reached the end of the juvenile period. Fresh weight, dry matter, nitrogen, starch and non-reducing sugars increase continuously during this period while the reducing sugars and acidity of peel and stone-kernel decrease. Acidity of pulp increases during the first fortnight and then begins to decline. The rate of respiration of the fruit also decreases.

Maturation. The main activity in the fruit during this second phase is the storage of starch. It occurs rapidly during the first half of the phase and then slowly marches to the peak value at the end. As cell-formation has ceased, this rapid accumulation of starch causes a sudden drop in the percentage of crude cellulose. The percentage of cell-wall incrusting material (acid-hydrolyzable matter other than starch), however, continues to increase during the whole of this phase.

There is a further increase in the concentration of non-reducing sugars in the pulp. The acidity of pulp, peel and stone-kernel appreciably decreases by the end of this phase. The respiratory activity of the fruit remains constant at a low value. All these changes indicate the approaching maturity. Externally it is indicated by the lightening of the colour, the appearance of a yellow flush, and the shoulder growing out of the stem-end. At this stage the fruits are removed from the tree.

Senescence. This period lasts for a fortnight. After picking, the fruits are first placed in the *adhi* for a week or so where they become fully ripe with the characteristic golden yellow colour. During this week rapid changes take place mainly in the pulp. The starch as well as the cell-wall incrustations are rapidly hydrolyzed and the

uit becomes soft an juicy. Most of the reduc-
g sugars formed are synthesized into sucrose.
e acidity is greatly reduced. The characteristic
ste and flavour of the mango are developed and
e fruit becomes edible.

Concurrent with the production of reducing
gars from the starch, the respiratory activity
the fruit suddenly shoots up and reaches the
macteric peak value which is nearly five
nes the rate of respiration at the beginning
the phase. The fluctuations in the respiratory
ivity closely follow the changes in reducing
gars of the pulp.

The fruits when completely ripe are removed
m the *adhi*. They remain in good edible
ndition for about a week more. The various
nstituents as also the respiratory activity remain
actically the same during this period.

After this the fruit begins to deteriorate. The
crose is rapidly hydrolyzed, the acidity increases
d the rate of respiration again shoots up to
high value.

Summary

The physiological changes taking place during
e growth and ripening of the Alphonse mango
ve been investigated. This variety requires 90
ys to mature on the tree. After removing
m the tree the fruit is kept in a warm place
ripening which takes place in about eight days.
e ripe fruit remains in a good edible condition
a week more after which the fruit begins
deteriorate. The changes in the carbohydrates
the pulp, peel and stone-kernel and in the res-
atory activity of the fruit have been studied
th during growth and during ripening. During growth the accumulation of starch is the main activity in the pulp. During ripening, the starch is completely hydrolyzed and the reducing sugars are mostly synthesized into sucrose. These changes in carbohydrates can be satisfactorily explained by Kidd's hypothesis. The respiratory activity of the fruit gradually decreases up to maturity. But immediately after picking it shoots up to the climacteric peak value. The changes in respiration closely follow those in the reducing sugars content of the pulp.

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BLACK-TIP DISEASE OF THE MANGO

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(With Plate XIV and six text-figures)

Introduction

Damage of the mango crop is reported to occur in many areas in the United Provinces and Bihar due to coal burning brick-kiln (Bull's kiln) working near orchards. It is a method of manufacturing high grade bricks in large scale. It consists of a circular or elliptical trench dug in the ground, usually 6 ft. deep and 15-20 ft. wide. Bricks are piled in the trench up to ground level and burnt in sections, lot by lot. When one lot is under the process of burning a fresh one is piled in front of it, so that the latter could be set on fire as soon as the first one is completely burnt. The burnt pile is eventually dismantled and the bricks removed. In this way the kiln is made to work as a continuous process. A lot takes about seven to ten days, according to its size for complete burning.

The pile prepared for burning is fitted with two moveable chimneys on top. The bricks are arranged in the pile in a special manner leaving appropriate gaps for air circulation within it, and a series of fuelling holes from its top. The fuelling holes are provided with iron lids. The two sides of the trench form two of its walls, the side in front, i.e. the side on which fresh bricks are piled, is closed with iron sheets, the top and the rear side up to about a foot from the bottom are appropriately prepared and plastered to close any passage of air. The arrangement is such that when the preparation of the pile is complete and it is set on fire, a draft of air enters it through the bottom of the rear side, which circulates within the pile and issues out through the chimneys. The chimneys are fitted close to the front side of the pile so that the draft of air can be made to traverse the pile from one end to the other. It ensures a more or less uniform burning of the bricks in the pile. Low grade coal is generally used as fuel. The coal is introduced at short intervals, usually every 15 minutes, throughout day and night so that practically a continuous flow of smoke issues out of the chimneys. The smoke is dark and heavy and has a considerable volume. In calm atmosphere it slowly spreads round, but otherwise it is blown wind-ward. T chimneys are necessarily short as they have fr quently to be moved from place to place. Genera ly they are 15-20 ft. in height. Due to the sho chimneys the smoke spreads in low heights so th where there are orchards near a kiln it can be se to flow through the trees. The intensity of t smoke is, no doubt, the less the farther it mov from its source.

Bricks are manufactured during the dry month Preparations commence soon after the rains abo November, and the kilns are seen busy worki from December-January until the rains set in aga about next June. This period coincides with t mango season and it is believed that the dama mentioned above is caused by the smoke of t brick-kiln.

The symptoms of black-tip disease

The damage usually becomes apparent when t fruits attain about an inch in length. At fi there is a yellowing of their distal end (tip). T goes on becoming more and more intense and tak on a dark brown tinge and finally turns blac When it is black the tissue is completely de and dried up. Such blackening always starts the very tip in a small patch and then progr sively increases. In extreme cases, practically t whole of the fruit, except a very small portion the stalk end, is destroyed (Plate XIV, fig. 1).

These symptoms are peculiar to this alleg smoke damage, and as it invariably starts from t tip it is called 'black-tip' disease of the mang It is quite distinct from *koeli* or *koel-padda** whi refers to dark spots on any part of the skin of t fruit due to mechanical injuries or any oth cause.

From experience the belief that the brick-ki smoke is the cause of black-tip of the mango fairly deep rooted among the people. Wherev the damage can be traced a brick-kiln is fou in the vicinity. Beautiful orchards produci healthy fruits before a kiln existed in the area a

* *Koel*=Cuckoo, also symbolical for blackne *Koeli* or *Koel-padda* =referring to blackening

FIG. 1. *Top three figures* show three stages of black-tip damage on Calcuttia Bombai mangoes in an orchard about 100 yds. east of an operating brick kiln at Laluchak, Bhagalpur.

Bottom three figures show three comparable stages of the black-tip effect on Sakerchina mangoes experimentally exposed to coal smoke at the Fruit Research Station, Sabour.

FIG. 2. Black-tip effect on fruits of mango (var. Sakerchina) as a result of experimentally exposing them to coal smoke at the Fruit Research Station, Sabour. Some fruits were left hanging normally while others were held with their tips at different angles, but the disease always initiated from the tips.

nd to show the damage as soon as a kiln is ted near them. Again the same orchards over when it is abandoned. When the damage urs it is found to be most severe in orchards ated on the easterly and westerly sides of rating kilns. During the mango season wind nost frequent in these directions. The damage inverse rates to the distance of orchards from s. Woodhouse [1909] noted the phenomenon he Sabour College of Agriculture, Bihar, as y as in 1908. At that time two kilns were up at Sabour for the manufacture of bricks uired for building the College Estate. The s were abandoned in 1909 and there has been case of black-tip in the locality since then.

gations

On the strength of this belief, certain growers d suits in courts claiming damages from brick- n owners in Bihar, the United Provinces Bengal. The decision of the court was not form. Sometimes the decree was in favour of growers, sometimes of the kiln owners. In ew cases scientists were invited as witnesses by h sides, but in the absence of any reliable ex- imental proof no uniform conclusion could be ived at.

evious studies

The Government of the United Provinces in- tuted an enquiry* into the quesion of black-tip ease in 1929-30. It was found that this damage d only recently become a menace to the mango p in certain parts of the province. With the t growth of cities like Cawnpore, Lucknow, . an increased number of kilns were started near h localities for the supply of bricks for building rposes. The kilns were situated as near as ssible to cities and business centres. These re also the places where there were extensive ngo plantations put in, owing probably to the oximity of markets. The damage could be found ly in areas where there were brick-kilns working ring the mango season and, therefore, it was ought that brick-kilns were responsible for it. t it was not ascertained whether the injurious ect of the kiln was due to the deletarious gases e SO_2 and ethylene which are present in the coal oke or due to a rise in temperature of the joining soil and atmosphere. Laboratory ex- riments had completely failed to reveal any cterial or fungal organisms causally related to e damage. In the enquiry it was also found at some varieties of mangoes appeared to be ore easily damaged than others.

When the Fruit Research Station at Sabour was established in 1934, its attention was also drawn to this problem. Naik [1934] made an investigation into the matter and came to believe that the popular observation that brick-kiln smoke causes the damage was correct.

Allan [1936] writes—'There is no doubt whatsoever that modern coal burning brick-kiln is a definite menace to a garden. Whether this damage arises as some think from the heating effect of the kiln on the soil nearby or, as the writer believes, from the fumes emitted may not be a settled matter ; but undoubtedly such a kiln specially if to the wind-ward, i.e. to the west or south-west (between March & June) of an orchard seriously endangers the fruit which in consequence is apt to develop a blackening of the skin......'.

Pal, Chatterji and Ranjan [1937] and Ranjan and Jha [1940] also believe that the black-tip on mango, occurring near brick-kilns, is caused by the gases of the coal smoke issuing from the kilns.

Das Gupta and colleagues [1939, 1940 & 1941] confirm that no parasitic organisms like bacteria or fungi are causally related to black-tip of the mango. They do not find any virus connected with it. Neither do they think that vigour of the tree or soil condition is responsible for the damage. Trees otherwise perfectly healthy show black-tip on their fruits. As regards soil, the damage is recorded in diverse localities where the soil conditions are different, but the disease is quite common in the immediate vicinity of brick-kilns. They do not, however, come to any definite conclusion as to the cause of the damage.

Smoke injury to vegetation

Loss to agriculture and forestry by industrial smokes has attracted the notice of scientists and administrators for nearly a century now. There have been litigations, commissions set up, and regulations enacted, in many countries. The dangers involved in attempting to grow plants in or near industrial centres have been discussed in numerous papers, bulletins and books [Sen, 1943] Of the coal fume gases sulphur dioxide, ethylene and carbon monoxide have been found toxic to plants and of these the first named is the worst offender. The experts of the Selby Smelter Commission [Zimmerman & Crocker, 1934] determined that practically all of the injury to vegetation was due to sulphur dioxide gas which was liberated in large amounts and was carried for long distances in sufficient concentration in the atmosphere to cause injury to plants. Smoke has been found to injure leaves and fruits [Kallbrunner 1924]. The injury takes place from the exterior and not through the roots as a medium, and it is made manifest by causing plasmolysis,

* From correspondence with Dr A. K. Mitra, Eco- mic Botanist to the Govt. of the United Provinces

derangement of chloroplasts, cell disintegration and a deficiency in the food supply [Brizi, 1903, cf. Blakke, 1913]. It has been found that smoke injury extends in the direction of the prevailing wind, that trees can be injured up to a considerable distance, and that some plants are more resistant than others. [Widtsoe, 1903; Haywood, 1907-cf. Blakke, 1913].

For control of smoke injury installation to industrial plants of such fixtures as will make them smokeless or at least absorb the harmful gases has been suggested. It is mentioned [Blakke, 1913] that brick-kilns could be made practically smokeless (by the installation of certain fixtures to them, by the Barber Asphalt Paving Co., U. S. A.). The use of high chimneys that will dilute the harmful gases coming forth, so as to make them harmless, has also been suggested. And as a partial assistance to a solution of the problem, setting out of only such plants as are relatively more resistant has been recommended.

The present work

During his visits to the mango-growing centres of the United Provinces and Bihar, the present author found that the extent of damage caused to the mango crop by this so-called black-tip disease was not negligible, and it was essential that some practical method be devised for its control. For such an attempt the first thing that appeared to be necessary was to come to a definite conclusion as to the cause of the damage. The surveys and experiments described below were undertaken with this end in view. They have conclusively shown that brick-kiln smoke causes black-tip damage of the mango crop. The critical time and stage of the crop at which the injury initiates have been determined and the distance from a kiln up to which it may extend has been noted, also, the mechanism of the black-tip effect discussed and possible method of minimizing it suggested.

Survey of the occurrence

To begin with, in 1939, the brick-kiln areas in one district, namely Bhagalpur, Bihar, were determined. It was found that the majority of the kilns in the district were situated round the city of Bhagalpur. The locality round the city was also a concentrated mango-growing area. A survey was then carried out five miles round Bhagalpur during the mango season of the same year. It consisted of an enquiry from growers, kiln-owners and experienced people of the locality, a general observation in all the different areas and a systematic examination of all the mango orchards in one area.

It was intended in 1940 to repeat the general survey carried out in 1939, and also to make some critical observations on flowers and developing fruits in a certain mango orchard which was adjacent to a kiln. Unfortunately, however, nothing more than making the observations on flowers only between 26 February 1940 and 25 March 1941 could be done as the mango crop all over the locality was spoiled by unusually heavy rains in March, and also the kilns were stopped because of the rains.

In 1941, the general survey was repeated and it was extended to the whole of the district of Bhagalpur. The same year, an intensive examination was made in two of the kiln areas round the city of Bhagalpur studying each and every mango tree within half a mile around the kilns: and two experiments were conducted,—(1) on the effect of enclosing in celophane bags fruits on trees exposed to brick-kiln fumes, and (2) on the effect of exposing healthy fruits on potted trees to brick-kiln fumes. Further, the occurrence of brick-kilns in the whole of the province of Bihar was determined together with information on the incidence of black-tip disease of the mango, and enquiries were made about this disease in all the mango-growing provinces and states of India through their agricultural and horticultural officers.

Survey of 1939

A map of the area five miles round the city of Bhagalpur showing the kilns therein, is presented in Fig. 1. A summary of the general information gathered from a survey of this region (during the three years, 1939-41) is given in Table I. In all, there were 38 kilns situated in 18 centres. Only in nine* of them, however, were there operating kilns. Those in others were abandoned. The oldest kiln recorded was started in 1881, but in as many as 8 out of the 18 centres kilns were started only since 1934. All the kilns were located within three and a half miles from the city.

No black-tip disease could be traced at a place within a mile of which there was no kiln. In the kiln areas black-tip was found only where there was at least one kiln in operation. In the areas where the kilns were abandoned no trace of the disease could be noted. It was, however, reported that when the kilns were in operation there occurred serious damage.

The growers and kiln-owners reported alike that black-tip of the mango appeared with the starting of brick-kilns near orchards. It was locally known

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* Only in eight areas kilns worked in 1939, work was resumed in the ninth area in 1940

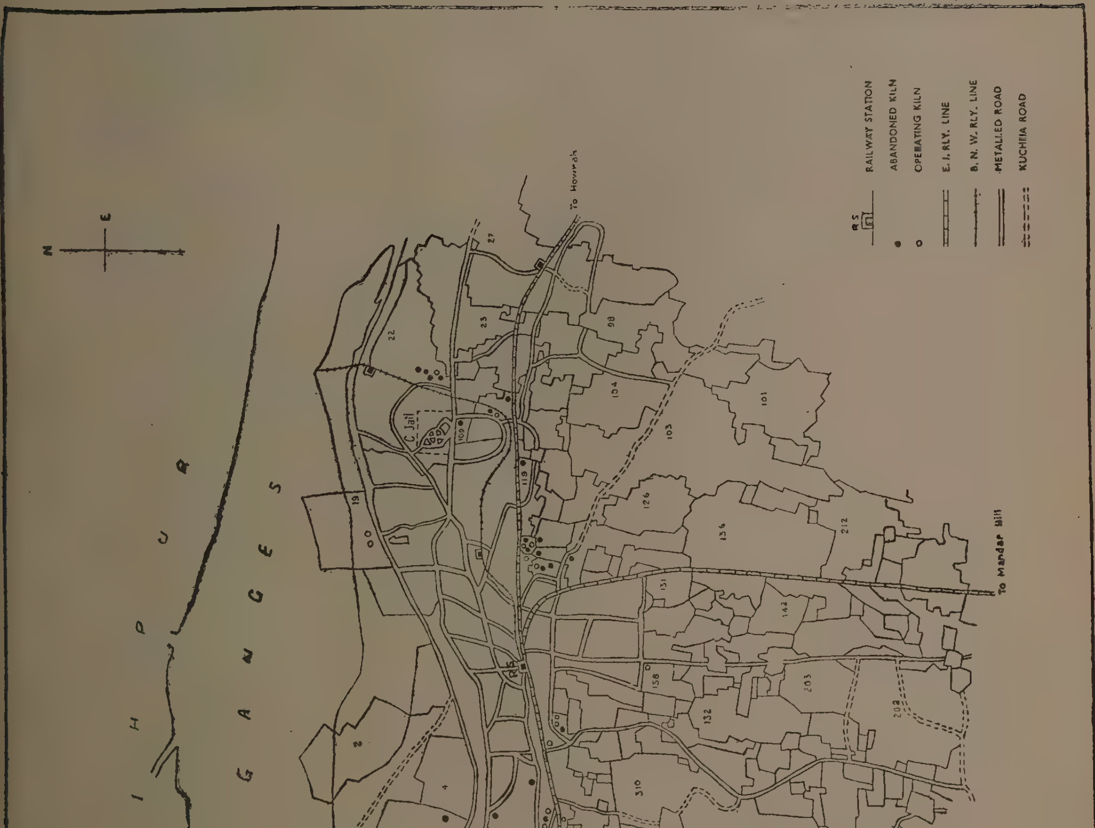


FIG. 1. A map of the area five miles round the city of Bhagalpur (Bihar) showing brick-kiln area (Scale 1 in. = 2 miles).

TABLE I

Brick-kiln areas and occurrence of 'black-tip' of the mango

Kiln areas	Distance from Bhagalpur R. S. (Bee-line)		Kiln first started in	Number of kilns		No kilns working since	Mango plantations in the area	'Black-tip' damage of the mango (1) before starting, (2) during running, and (3) after abandoning kilns in the area			Remarks
				Running	Abandoned			(1)	(2)	(3)	
	Miles	Furlg.									
1. Laluchak .	1	2	1909	4	6	..	Concentrated all round	Nil	Seen	..	
2. Kabirpur .	1	6	1920	3	2	..	All round . .	,,	,,	..	
3. Manhera (Barari)	3	4	1908	1	3	..	Concentrated all round	,,	,,	..	*
4. Khanjarpur .	2	2	1925	2	Nil	..	Garden scarce, only a few trees on S.W.	,,	,,	..	
5. Jhurkhuria (Gopalpur)	3	..	1935	1	2	..	N., E. & S. . .	,,	,,	..	
6. Husanabad .	1	4	1936	1	Nil	..	Garden scarce, a few trees on N. only.	,,	,,	..	
7. Tewari Talao	..	7	1935	1	,,	..	On W. & N. . .	,,	,,	..	
8. Badralampur (Shahjangi)	1	..	1935	1	1	..	On S. & W. . .	,,	,,	..	
9. Maulanachak	..	6	1936	1	Nil	..	On W. only . .	,,	,,	..	
10. Sarmaspur .	1	3	1936	Nil	1	1939	Adjoining W. & N.W.	,,	Reported	Nil	
11. Shahebgunj .	1	6	1934	,,	1	1936	About all round .	,,	,,	,,	
12. Siranpur .	2	..	1929	,,	1	1931	N., E. & S. . .	,,	,,	,,	
13. Motipur .	2	4	1929	,,	1	1931	On S. only . .	,,	,,	,,	
14. Raghupur .	2	1	1936	,,	1	1937	S., E. & N. . .	,,	,,	,,	
15. Parbati .	1	2	1911	,,	1	1931	On W. only . .	,,	,,	,,	
16. Bahadurpur .	2	7	1881	,,	1	1891	On E. only . .	,,	,,	,,	
17. Jagatpur .	2	2	1901	,,	1	1939	Almost all round .	,,	,,	,,	
18. Jicho . .	2	6	1911	,,	1	1916	On W. only . .	,,	,,	,,	

* In 1939 there was no kiln working in this centre. No black-tip could also be traced in the area that year. A new kiln was set up in 1940. 'Black-tip' of the mango reappeared with it.

as *dhuiyan*† and the people were perfectly acquainted with its symptoms. The popular experiences and findings of the various authors mentioned in the introduction were fully corroborated by the inhabitants of the locality.

One of these centres called Laluchak was selected for a systematic and thorough observation. In one orchard in this area, situated only 50 ft. east of a running kiln, weekly observations were made. The observations were started in the middle of March and carried on till the end of April. The plot of orchard measured 350 ft. north-south and 200 ft. east-west. There were six rows of ten trees each. They consisted of the six important varieties of Bihar mangoes, namely, Bombai, Calcuttia-Bombai, Langra, Fazli, Zardalu and Kumarpahar. The trees were 13 years old at the time. All of them were healthy and vigorous. Even the trees nearest to the kiln showed no adverse effect on their growth and vegetation. All

† *Dhuan* = smoke; *dhuiyan* = caused by smoke

the trees produced new flush which appeared in all respects normal, even when they had diseased fruits on them.

The time of appearance of symptoms. Till the end of March when the fruits were not yet bigger than a pea in size, no symptom of black-tip could be detected, fruit set appeared normal in all respects. With the increase in size of the fruits the symptom became apparent by the first week of April when the fruits were one and a half to two centimeters in length. All the varieties except Fazli showed the symptom by this time. The Fazli was a late variety and the fruits were also relatively smaller than those of the others at that time. By the middle of April, however, even the Fazli fruits showed the symptoms. The fruits of all the varieties including Fazli were 2-3 cm. in length at this stage.

The time of initiation of the damage, however, appeared to be somewhat influenced by the distance of orchard from kiln. Thus in the same area and in the same direction black-tip was found to appear in Bombai and Zardalu trees situated at 1000 ft. to 1200 ft. about two weeks later than in the same varieties situated at 100 ft. to 200 ft. from the kiln. The fruits were about 8 cm. in length at that time. Similar experience was reported by many growers in the various centres.

Varietal difference. The different varieties in the orchard under observation were found to be affected to different degrees. The Calcuttia-Bombai and the Zardalu mangoes showed the maximum damage. By the end of the third week of April when the fruits were about 5 cm. in length, nearly the whole of the lower half of many of the fruits in these two varieties were blackened and dried up, while hardly a single fruit was left unaffected. In the cases of Bombai and Kumarpahar as well, almost each and every fruit was affected but the maximum damage on a single fruit did not invlove more than a quarter of its distal end. The Langra and Fazli varieties showed much less damage, relatively few of their fruits showed blackening and although the majority of them showed yellowing of their tips there were yet some fruits looking quite healthy. Between the last two varieties the Langra appeared to show greater damage.

The affected fruits in all the varieties showed a tendency of early dropping. The dropping also appeared to be proportional to the degree of damage. A good many of the fruits of the Zardalu and Calcuttia-Bombai varieties had dropped by the third week of April. The Bombai and Kumarpahar fruits showed lesser dropping, and the Langra and Fazli showed it still less. The few fruits that persisted on the trees showed premature ripening. The flesh of the unaffected upper portion of these fruits when ripe was found tough and devoid of flavour though, perhaps, somewhat sweeter than a healthy ripe fruit.

Near another running kiln in the same area, there were two mango trees growing side by side. One of them was a Kumarpahar and the other a Golbhadaiya tree. Almost each and every fruit of the former was severely damaged, while in the case of the latter only the fruits on the kiln side had developed actual black-tip, those on the opposite had either shown only yellowing of the tips or no symptom at all. A cursory examination of the fruits suggested that the varieties which were relatively more susceptible to this damage had a less hardy appearance. Incidentally, the thickness of skin of the fruits of all the above-listed seven varieties of mangoes was determined anatomically. The data are presented in Table II. Calcuttia-Bombai shows the thinnest skin and Langra the thickest, but no concomitant relation between skin thickness and the degree of damage can be established.

TABLE II

Thickness of skin of mango fruits

(Average of six fruits in each case, determined on 22 April 1939)

Variety	Average length of fruits in cm.	Thickness of skin in µ			
		Shoulder	S. E.	Tip	S. E.
Bombai	4·9	704·7	9·3	669·9	30·5
Langra	5·2	872·9	12·8	823·6	53·8
Fazli	4·8	472·7	13·1	469·8	10·9
Calcuttia-Bombai	5·1	287·1	14·7	278·4	18·9
Kumarpahar	4·9	577·1	43·3	559·7	32·1
Zardalu	4·4	629·3	78·9	594·5	86·5
Golbhadaiya	5·6	690·2	8·8	667·0	21·1

In all the kiln areas such varietal difference in the degree of damage could be observed. Hemsagar was another very susceptible variety.

Incidentally it may be mentioned here that within 200 ft. east of the first kiln there was a litchi (*Litchi chinensis* Sonn.) plot. The litchi and mango flower and set fruit about the same time. At the time the disease was noted on mango in adjoining plots as well as on a plot on the east beyond the litchi one, the litchi trees were laden with developing fruits, none of which showed any sign of adverse effect like the mangoes. They were all healthy. On enquiry from growers in the

locality it was gathered that the litchi shows no adverse effect like the mango. Enquiries were also made about the possible effect of the kiln fumes on other fruits, e.g. guava (*Psidium Guajava* Linn.), a few gardens of which were noted in kiln areas. The main season of guava extends from June to October-November, when the kiln does not work. A second crop, however, is often found during winter. No damage to this fruit was reported. Injurious effect of fumes on wheat crop in the vicinity of brick-kilns, through turning the leaves pale, has, however, been reported from more than one sources. Similar effect on leaves of the jack fruit (*Artocarpus integrifolia* Linn.) has been reported.

Distance and direction from kiln. In the above-mentioned orchard in which weekly observations were made, the position of the tree was found to make appreciable difference as to the degree of damage. Fruits on trees occurring on the row nearest to the kiln showed definitely more severe damage than those on similar trees of the same varieties occurring on the rows farther from the kiln, and in general, the northern quarter of the orchard showed the most severe damage.

As already mentioned, this orchard was situated only 50 ft. east of an operating kiln. There was no other kiln farther east of this one. The kiln and the orchard were on about the same level. Between the two there was a row of palm trees grown on the west border of the orchard. Draughts of dark smoke, in thick volume, were found to issue out of the chimneys of the kiln every 10-15 minutes, as fresh coal was added. The smoke could be seen to be blown by the wind and trickle through the palmyra trees into the orchard. At times the smoke came in such thickness that minute particles of coal dust could be seen to drop on the orchard, and the smell of coal smoke very strongly felt. Occasional observations and enquiry from the keeper of the garden led to believe that the northern part of the orchard which was towards the north-east of the kiln was exposed to more direct flow of the smoke than the rest of it, as the wind blew more frequently in that direction.

On all sides of this orchard, except west, there were mango plantations. Black-tip was traced in the Bombai mango as far as 1000 ft. from the kiln. Fazli and Langra mangoes occurring only at 500 ft. to 600 ft. east of the kiln appeared unaffected. On the north-east side damage could be seen in the Zardalu variety up to about 1200 ft. from the kiln. On the north, black-tip could be traced in the Hemsagar and Zardalu mango up to about 400 ft. On the immediate west of the kiln in question there were no mango orchards. On the west of another operating kiln, in the same area, about two furlongs west of this kiln, however, black-tip was found in Bombai, Langra, Fazli, and on certain seedling mangoes up to 700 ft. farther west, there were no plantations. On the south-west of this second kiln black-tip could be traced in Zardalu and Bombai varieties up to 1100 ft. Near a third kiln, in the same area, black-tip was traced on the south in Zardalu and Hemsagar varieties up to about 550 ft.

Ditch between kiln and orchard. In many areas, it was very interesting to note that the operating kilns were separated from the orchards by huge ditches due to digging the earth, year after year, for making bricks. The presence of such ditches appeared to make no difference at all as to the occurrence of black-tip damage in the area across them.

OBSERVATIONS OF 1940

Samples of flowers collected from the different varieties of mangoes in the orchard at Laluchak in which weekly observations were made in 1939 were examined every week, between 26 February and 25 March 1941. The kiln near this orchard was in operation. As already stated, the study had to be abandoned after this stage as the flowers were spoiled by unusually heavy rains.

The flowers were examined under a dissecting microscope with a view to determine if the developing ovaries showed any effect. They were compared with flowers of the same varieties collected on the same dates from trees of about the same age and vigour, at the Fruit Research Station, Sabour, where black-tip was not known to occur. No effect was found.

SURVEYS OF 1941

Five miles round the city of Bhagalpur

The general survey made in 1939 was repeated. The observations made in that year were confirmed. In Manbhara (Barari) there was no kiln operating in 1939, neither could any black-tip be traced in the area. In 1941, on the other hand, serious damage was noted round a kiln which was working that year.

District of Bhagalpur

Besides those round the city of Bhagalpur, operating brick kilns were found in the district only on the outskirt of the Sub-Division town of Madhepura. There were two running kilns, one about two furlongs west of the town and the other about three furlongs due south of the first one. The locality is, however, not a mango growing tract. There are only a few plantations scattered here and there.

Black-tip was noted at about 800 ft. east of the first kiln on a Bombai and two seedling trees. These were the nearest trees bearing some crop. About 300 ft. further east there were seedling trees bearing fruits but they did not show any damage. On the north-west of the second kiln

black-tip was noted on some seedling mango trees at about 1500 ft. There were no mango trees near the kilns on any other side.

Intensive survey in two areas

An intensive examination was made in two of the kiln areas round the city of Bhagalpur. Manbhara (Barari) and Laluchak were selected for the purpose as these were the only two areas where concentrated mango plantations could be found on most sides of kilns. At Manbhara there was only one kiln in operation. Each and every tree within a radius of half a mile from it was studied. At Laluchak, on the other hand, there were four running kilns. The one on north-east was selected as centre, as it was found to include the maximum number of the plantations within half a mile round it. In this case as well, all the individual trees were studied. Survey maps of these two localities showing the holdings of the people were obtained. With the help of these maps the area to be examined was first determined. Each individual mango plantation within the area was then plotted to show the plan of the orchard, the varieties of mangoes, the trees having fruit or not, showing black-tip damage or not, and the degree of damage. The damage was recorded in three degrees, namely (i) fruits showing marked blackening of their distal ends, (ii) marked yellowing with slight blackening of tips and (iii) yellowing of the tip only,—hereafter they have been described as (i) black-tip, (ii) black and yellow-tip and (iii) yellow-tip, respectively. A tree showing damage on at least a single fruit was taken as affected. In addition to the above records, in each case, the age of the plantation, the name of the owner and any other relevant information were noted. A part of such a plot, shown in Fig. 2, will explain the method employed. The actual observations on fruits were made between 24 April and 22 May, 1941.

In the Manbhara area a total of 126 plots holding 8551 trees belonging to 54 varieties and seedling mangoes, and in the Laluchak area 132 plots holding 5094 trees of 42 varieties and seedling mangoes were thus studied. Between the two plots there were 62 different varieties, 34 being common. In Figs. 3 and 4 are presented the maps of the two areas showing the kilns, mango orchards and the trees affected by black-tip.

The map of the Manbhara area (Fig. 3) is divided into 16 sectors indicating the directions of the orchards from the kiln. It could not, however, be conveniently done so in the case of Laluchak area (Fig. 4). Due to the presence of more than one operating kiln in this area, a particular plot falls in different angles from the different kilns. In this case the direction of a plot from the nearest kiln has been noted. In all cases the distance of a plot or a tree from a kiln has been estimated from map and not by actual measurement in the field. The direction and distance of a plot from an operating kiln, its age, the varieties of mangoes present in it, fruiting or not, whether affected or not, etc. are shown in tabular form in Appendices A & B.

Manbhara (Barari)
Plot—A. 15 (southern part)
Age of orchard—40 years
Owner—Dukha Gope, Barari

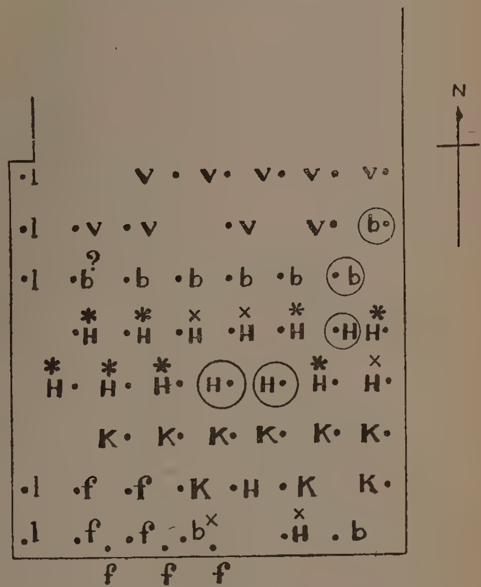


FIG. 2. Showing method employed in the intensive survey for recording incidence of black-tip disease
b = Bombai l = Langra f = Fazli
H = Hemsagar v = Bharatbhog and
K = Krishnbhog
* = black-tip x = black and yellow-tip ? = yellow-tip and O = no effect

A glance on either of the two maps will clearly show that the damage is most severe on the easterly and westerly sides of the operating kilns. At Manbhara kiln was first started in 1908. Due to excavation of earth for making bricks since that time, a huge ditch is formed and the kiln in operation looks like an island in it. The ditch is indicated in the map by broken lines. Its width on east is 300 ft., on south 400 ft., on west 300 ft. and on north 1000 ft. It is 16 to 17 ft. deep on all sides, except for a sloping cart road, on the west. Towards the south (ESE, SE, SSE, S, SSW & SW Sectors) of the kiln there are a few mango trees falling in plot B4 and part of B2, actually planted in the ditch*. There is one tree almost on the border of the kiln, on the south on same level with it. It is hardly 30 ft. from the kiln. It shows

* It is a very old kiln area. A few mango trees were actually planted some years ago in this the older part of the ditch

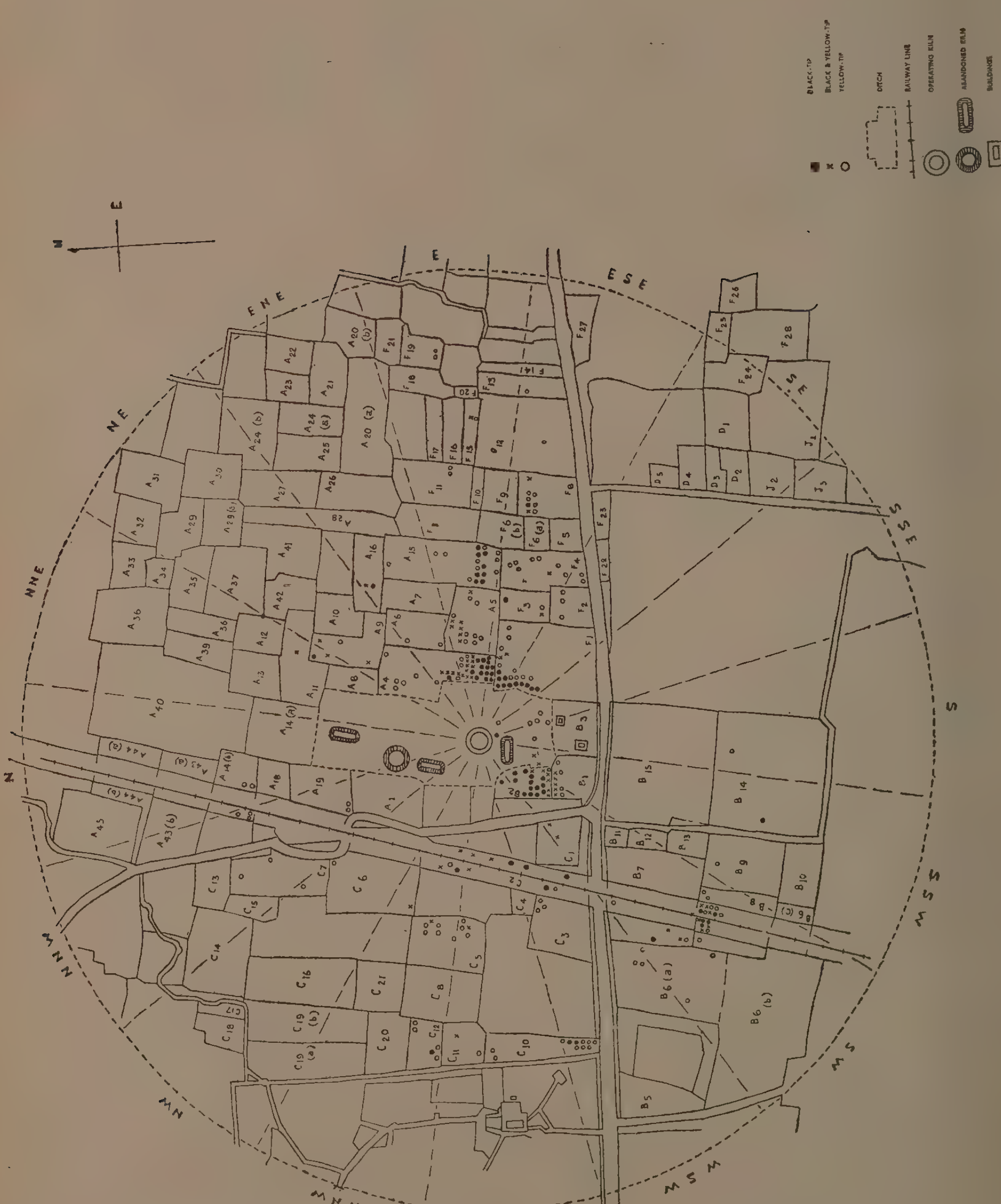


FIG. 3. A map of Manbhara (Bhagalpur) brick-kiln area showing incidence of black-tip disease of the mango crop over half a mile round an operating kiln in 1941 (Scale 16 in.=3 miles)

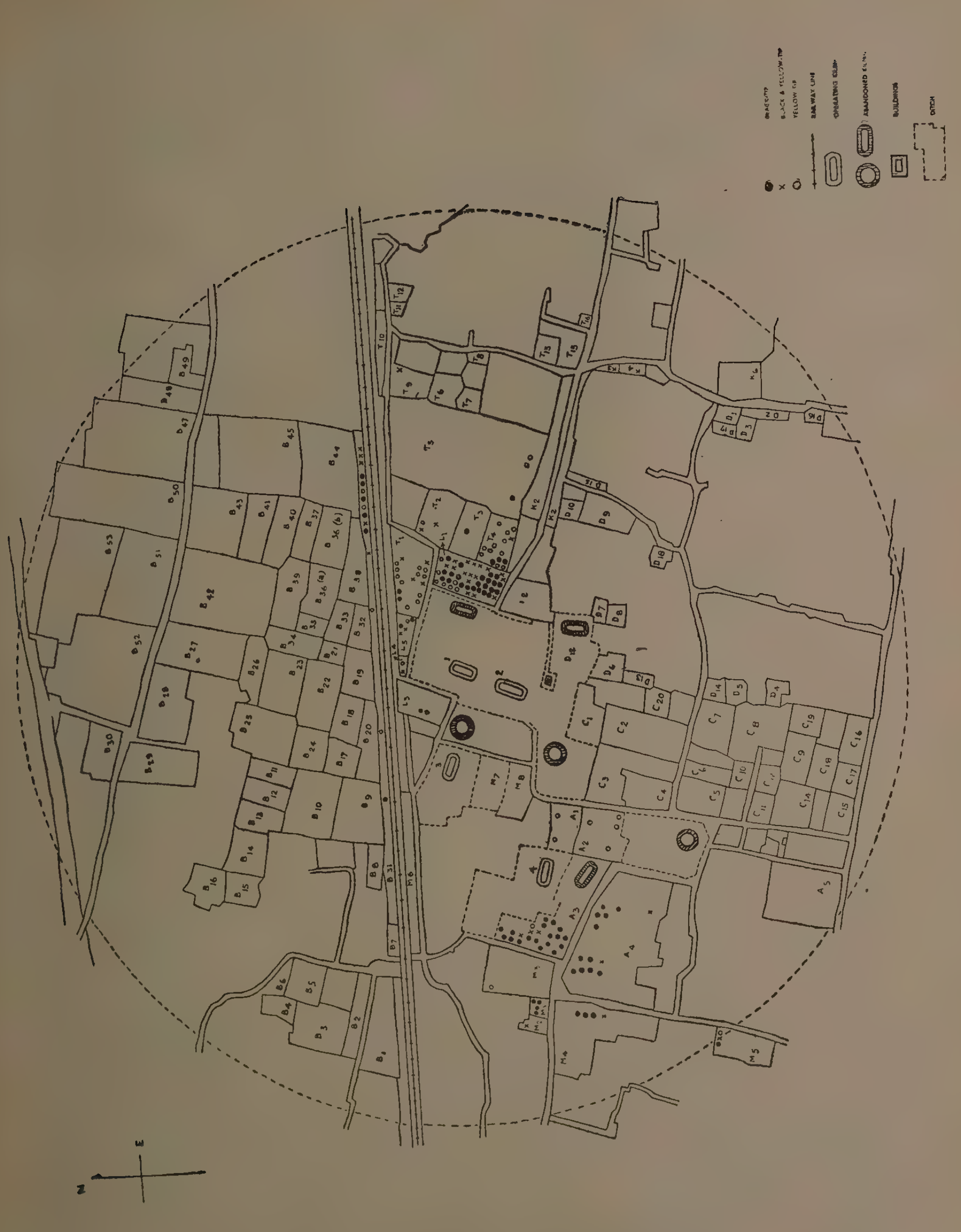


FIG. 4. A map of Laluchak (Bhagalpur) brick-kiln area showing incidence of black-tip disease of the mango crop over half a mile round operating kilns in 1941 (Scale 16 in. = 3 miles)

black-tip on practically all its fruits, but otherwise it is perfectly healthy. Hardly another 10 ft. from the kiln there is a tree in the ditch. It shows only yellow-tip. Both these and most of the other trees in the ditch are seedling mangoes. Some of them show yellow-tip. There are, however, one plant each of Fazli, Zardalu and Kaitki, with them. The Kaitki shows black and yellow-tip and the other two show yellow-tip only. Across the ditch up to 500 ft. from the kiln practically each and every tree bearing fruit, irrespective of variety, is affected. In certain sectors and in certain varieties the damage is present much farther. Thus in sector E, Hemsagar shows black-tip up to 1000 ft., Bombai up to 700 ft., whereas Bharatbhog and Fazli show only black and yellow-tip even at 350 ft. and 600 ft. respectively. In the same sector yellow-tip is noted in Hemsagar up to 2050 ft., in Kadua 1450 ft., Bombai 1000 ft., Langra 700 ft., Fazli 670 ft. and Bharatbhog 400 ft. In Table III are listed the affected varieties showing the directions and distances up to which the damage is found on them. Seedling mangoes are not mentioned in this table.

TABLE III

Occurrence of 'black-tip' in mango varieties, degree of damage and distances (in ft.) and direction from operating brick-kiln

Variety	Marked blackening	Marked yellowing with slight blackening	Yellowing only
1. Bombai . . .	700E ; 700ESE ; 360SW ; 1600WSW ; 180W	900E ; 900ESE ; 1560SW ; 630W ; 630ENE	1000E ; 1000ESE ; 1700SW ; 1740 WSW ; 1650W ; 1080 WNW ; 990 NNE ; 690NE ; 1080ENE
2. Langra . . .	270ESE	370ESE	700E ; 570ESE
3. Fazli	....	600E ; 270SSW ; 590ENE	670E ; 1050SW ; 1050WSW ; 400NE
4. Zardalu . . .	270ESE ; 270SE ; 1080NNE; 360ENE	300SE	1000SE ; 270SSE ; 400SSW ; 400SW; 960WSW ; 700NE;
5. Hemsagar . . .	1000E ; 1250ESE ; 1650SSW ; 1600SW ; 1710WNW ; 1000NE	1900E ; 1400ESE ; 1620SW; 1650W ; 1650WNW ; 1080NNE ; 1050NE	2050E ; 1600ESE ; 800SE ; 1350S ; 1620SW ; 1740 NNW ; 1400N
6. Gulabkhas . . .	....	300SE	330SE
7. Bharatbhog . .	....	300E ; 300ENE	400E ; 300ESE ; 990WSW ; 1260NNE
8. Kumarpahar . .	....	390ENE ; 330SW	350 SW
9. Jalibandha . .	....	1710W	400SW
10. Jalsain . . .	....	930ESE	1450E ; 1000ESE ; 1600SW ; 900NNW ; 1370N
11. Kadua . . .	....	930 ESE	
12. Lilkalmi . . .	....	....	1600NNW
13. Golbhadaiya . .	350SW ; 360WSW	330ENE	330SE
14. Kaitki . . .	....	....	270SSW ; 1050WNW
15. Kapuria . . .	....	....	500NNE
16. Banka . . .	....	....	330ESE
17. Arhalua . . .	1400SW . . .	1530SW ; 1190NNE .	970SE
18. Lambabhudri . .	....	....	1440SSW ; 1815SW

Laluchak is also a very old kiln area. The first kiln was started here in 1909 and in this case as well there are huge ditches separating kilns and orchards. Here all the operating kilns are actually situated in ditch much below the ground level. The depth of the ditches varies from 13 to 18 ft., their sizes may be gauged from the map. Towards the east of kiln 1 and west of kiln 4 severe damage is noted up to about 600 ft. There are few plantations on the east or west of kilns 2 and 3. In general, this area had much poorer crop than at Manbhara. The varieties, excluding the seedling trees, that show the damage are listed in Table IV, together with their distances and directions from running kilns.

TABLE IV

Occurrence of 'black-tip' in mango varieties, degree of damage and distances (in ft.) and directions from operating brick-kiln

Variety	Marked blackening	Marked yellowing with slight blackening	Yellowing only
1. Bombai	830WSW ; 430W ; 390WNW ; 430NW ; 630E ; 660ESE ; 560ESE	1300WNW ; 760ESE ; 600ESE	1350SW ; 330ENE ; 330NW ; 460NNE ; 1260ESE
2. Langra	360WNW ; 360NW ; 600E	350WNW ; 630E	860WSW
3. Fazli	560WSW ; 530E ; 490ESE ; 690ENE	600E ; 690ENE	200ESE
4. Zardalu	500SSW ; 1050SW ; 560ESE ; 760ENE ; 530E	660SSW ; 1350SW ; 1750E ; 600ESE	330ESE ; 600ENE ; 530E
5. Hemsagar . . .	430SW ; 1220ENE ; 790E	890NE ; 1350ENE	660NE ; 1120ENE
6. Bharatbhog . .	....	600ENE	860ENE
7. Golbhadaiya . .	830WSW	600WSW	
8. Kadua	430NNW ; 860WNW		
9. Sukul	....	860E ; 990ENE	
10. Darma	....	860ENE	
11. Mohanbhog . .	....	690ENE	

A strict comparison of the varieties regarding the damage cannot, however, be expected in such a survey, as they do not occur in the plantations in a regular manner. Sufficient data, however, seem to be there to show that different varieties are affected to a different degree. Out of the 61 varieties present in the two areas only a few are of commercial value. Thus Bombai, Langra and Fazli are the most important mangoes of Bihar. Zardalu, Hemsagar, Gulabkhas, Bharatbhog, Kumarpahar, Sukul and Darma are also very good mangoes. Damage could be traced on all these and a number of others, namely Jalibandha, Jalsain, Kadua, Lilkalmi, Golbhadaiya, Kaitki, Kapuria, Banka, Arhulwa, Lambabhadri and Mohanbhog. The remaining varieties on which black-tip is not recorded either do not occur sufficiently close to a running kiln or show no fruiting. Among the three most important mangoes, Bombai, Langra and Fazli, the first one shows the greatest effect. Damage can be traced in this variety up to 1700 ft., on Fazli up to 1050 ft. and Langra 700 ft. from the kiln. Black-tip can be traced up to a maximum distance of 2050 ft. in Hemsagar.

TABLE V

Showing direction and average velocity of wind during March, April and May

Wind direction	1939		1940		1941	
	Days	Average velocity	Days	Average velocity	Days	Average velocity
E. . .	9	7·8	11	5·9	13	8·3
E.S.E. .	10	7·4	2	8·0	3	8·0
S.E. .	1	4·0	7	4·2	2	4·5
S.S.E .	2	4·5	5	6·7	8	4·0
S. . .	4	5·7	2	3·5	2	4·5
S.S.W. .	3	6·8	5	3·9	4	6.5
S.W. .	4	6·5	6	6·1	12	6·8
W.S.W. .	8	8·2	7	8·1	10	6·7
W. .	3	7·5	9	7·5	12	8·2
W.N.W. .	2	9·5	3	8·0	1	9·0
N.W. .	1	6·0	2	5·0	1	2·0
N.N.W. .	1	2·0	..	0·0	2	5·5
N. . .	..	0·0	2	4·5	1	5·0
N.N.E .	5	5·8	..	0·0	..	0·0
N.E. .	6	4·4	8	4·7	4	7·3
E.N.E. .	23	6·3	8	5·7	11	5·0
Calm .	[illegible]	..	12	..	6	..

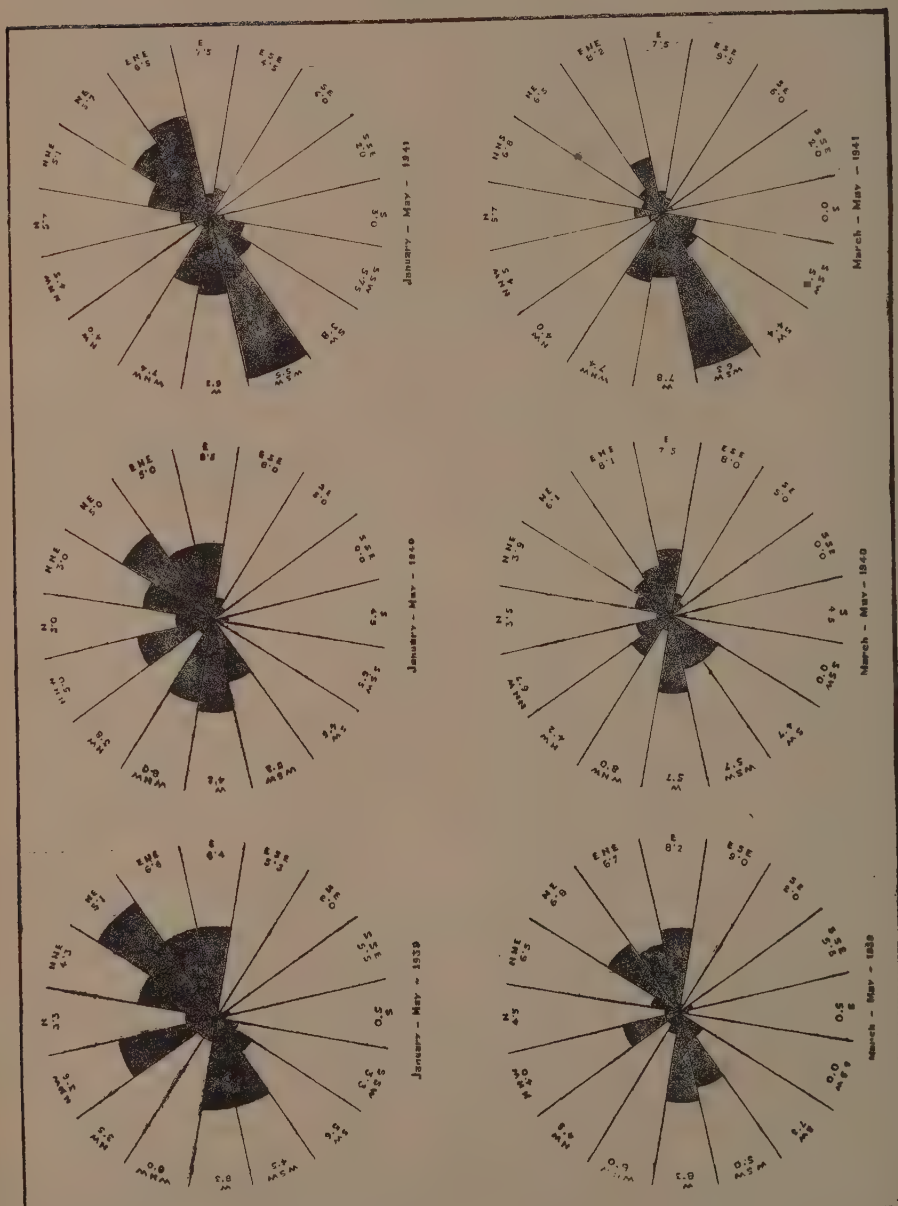


FIG. 5. Showing the number of days for which wind blew in a particular direction during the specific periods. The figures in each sector represent average velocity of wind

Directions and average velocities of wind recorded at the Meteorological Sub-station at Sabour, between March and May, in 1939, 1940 and 1941 are shown in Table V. The wind directions are also diagramatically shown in Fig. 5. It appears clear that mostly easterly and westerly wind blows during this period. A comparison of the diagrams for 1941 in Fig. 5 with Figs. 3 and 4 suggests that the direction and velocity of wind play important part in the distribution of black-tip damage.

Two incidental experiments

Along with the surveys of 1941 certain observations were made on the effects of bagging mangoes on trees exposed to brick-kiln smoke and also of exposing fruits on potted mango trees to brick-kiln fumes. The experiments were rather incidental but they deserve mention as the indications obtained from them appear to be definite and they go to confirm the view that the smoke of the kiln is the cause of the black-tip disease of the mango.

1. *Bagging of fruits on trees exposed to smoke*

This experiment was carried out in the orchard at Laluchak (Bhagalpur) in which the weekly observations in 1939 and 1940 were made (Fig. 4, plot L_1). The kiln only at about 50 ft. west of the orchard that was in operation in those two years was now abandoned. A kiln at about 350 ft. in the same direction and another at about 500 ft. south-west of the orchard were, however, in operation. There was no other orchard between this and the kilns.

On 12 March 1941, when some flowers had already set fruit and some had just opened, 25 panicles were enclosed in ordinary celophane bags on five Zardalu and one Fazli trees in row 1 and one Fazli and two Bombai trees in row 2, from the west, at the rate of two or three panicles per tree. The panicles on each tree were so selected that on the same branches there were several more panicles of similar development. On 14 March 1941, therefore, another 20 panicles were enclosed in fine muslin bags on the same two and another two Bombai trees in row 3, and one fresh Fazli and one Langra trees in row 2. The minimum number of panicles enclosed per tree was two. Weekly observations were then made on the bagged and unbagged panicles on the trees from 16 March 1941. The bags were opened for about five minutes every three or four days including the dates of observations.

On 16 March 1941, all the bags were found in perfect condition and the enclosed panicles also looked fairly healthy. None of the trees showed black-tip although some unbagged fruits on the Zardalu trees were suspected to show yellowing of tips. The biggest fruit on the tree measured 2 cm. in length. In another seven days, i.e. by 22 March 1941 as many as 20 out of the 25 celophane bags were torn. Only one each on three Zardalu trees and two on a Bombai tree were entire. The bagged panicles showed signs of withering and most of their fruits and flowers had dropped. In the five entire celophane bags only eight fruits were persisting—two each on two Zardalu and one Bombai and one each on a Zardalu and a Bombai panicle.

On this date all the Zardalu trees were affected. Almost each and every fruit on the trees showed yellowing of tips and in many cases blackening started. The five Zardalu fruits within the three entire celophane bags, however, appeared unaffected. No other trees showed black-tip on this date.

On 1 April 1941, all the five celophane bags were found all right but the panicles in them looked more withered than before ; all but three fruits on the three Zardalu panicles had dropped. At this stage black-tip was very pronounced in the Zardalu trees, each and every fruit on them appeared to show a black patch at the tip, but the ones in the bags appeared unaffected. In another three days, i.e. by 4 April 1941 even these fruits dropped, but none of them showed any sign of black-tip.

The panicles in the muslin bags began to show signs of withering about 1 April 1941, and all but six panicles on the four Bombai and one on a Fazli tree withered away by 9 April 1941. On 22 April 1941, only five panicles had seven fruits still persisting on them. They consisted of six Bombai fruits on four panicles and one Fazli fruit on one panicle. At this stage all these trees were showing severe black-tip damage. The fruits were 4-5 cm. long. Each and every unbagged fruit was found affected, but the bagged ones appeared free from damage. The panicles holding the fruits did not, however, appear as fresh as the unbagged ones and the fruits also looked somewhat pale in colour. In another two days even these seven fruits had dropped.

2. *Exposing plants to brick-kiln smoke*

In the same orchard eight three-year old potted plants were placed on two suitably constructed platforms between the trees on the first row on 22 March 1941. The plants had one to two panicles each, which had begun to set fruit. On 1 April 1941, there were left only eight fruits—one each on a Kalapady, a Kachmahua and a Fazli, two on a Bharatbhog, and three on a second Fazli pot. The Fazli fruits were suspected to show yellowing of tips. At this time all the trees near the platform (Zardalu and Fazli) were showing severe black-tip damage. Two of the Fazli fruits showed distinct yellow tip in a couple of days but all the fruits dropped before any black spots could be detected.

Brick-kilns in Bihar

The localities where brick-kilns occurred in the whole of the province of Bihar were determined in 1941. The information on the types of soil in the different localities, whether or not there were mango orchards near kilns, and whether or not the black-tip injury was noted, are given in Table VI. There are sharp differences in the soils of the different places where kilns have been found. The disease was reported from all places where there were mango orchards near operating kilns, irrespective of soil conditions. Brick-kilns have generally been found near towns and business centres, thus brick-kilns have also been found at Jamshedpur, Ghatsila, Dhanbad, etc. in Chotanagpur which is not a mango-growing tract.

Table VI

Localities with brick-kilns and reports on the occurrence of black-tip in 1941

Locality	Soil	Mango orchards in the vicinity. Present = + Absent = —	Black-tip disease. Noted = + Not noted = —
Tirhut Division			
1. Narkatiaganj	Hard clay	—	—
2. Bettia	Light loam	+	+
3. Gopalganj	Ditto	—	—
4. Siwan	Ditto	—	—
5. Chapra	Ditto	+	+
6. Hajipur	Ditto	+	+
7. Motipur	Calcareous loam	—	—
8. Madhubani	Yellowish clay	—	—
9. Darbhanga	Sandy loam	+	+
Bhagaplur Division			
10. Madhipura	Ditto	+	+
11. Purnea	Ditto	—	—
12. Kishanganj	Ditto	—	—
13. Katihar	Ditto	+	+
14. Lukhisarai	Loam	—	—
15. Sultangunge	Ditto	+	+
16. Bhagalpur	Ditto	+	+
17. Barari	Ditto	+	+
18. Rajmahal	Ditto	—	—
Patna Division			
19. Arrah	Clayey	+	+
20. Aurangabad	Ditto	—	—
21. Patna	Clay loam	+	+
22. Biharsharif	Ditto	—	—
23. Dehri	Sandy loam	—	—
24. Warsaliganj	Clay soil interspersed with limestone nodules	—	—
25. Nawada	Ditto	—	—
Chotanagpur Division			
26. Dhanbad	Uplands reddish loamy, lowlands brownish clay	—	—
27. Lesliganj	Loose gravelly	—	—
28. Barhi	Hilly lateritic	—	—
29. Hazaribagh	Ditto	—	—
30. Gumla	Ditto	—	—
31. Jamshedpur	Ditto	—	—
32. Ghatsila	Ditto	—	—
33. Baharagaon	Ditto	—	—

Occurrence in other parts of India

Besides Bihar and the United Provinces the disease has been reported from Bengal and the Punjab in localities where brick-kilns are found to work near mango orchards. It is not noticed in the mango tracts of Madras, Mysore, Bombay and Baroda, at the same time it is reported that the modern coal burning brick-kilns are not much in vogue in these parts and these are not seen near mango orchards.

The Economic Botanist, Bengal, writes* '—— Black-tip disease of mango has been observed in some of the gardens in Malda which are adjacent to brick-kilns. It can be said definitely that the smoke from the kilns is responsible for this injury. The fruits of the gardens situated far off from the kilns are not affected'.

The Fruit Specialist, Punjab, writes* '—— in Jagadhari, I found two mango groves situated near a brick-kiln where most of the fruits on the trees (largely at the apex) showed a yellow spot which blackens subsequently and decay in due course. On some trees I found almost cent per cent of the fruit affected ——'.

Effects of coal fume

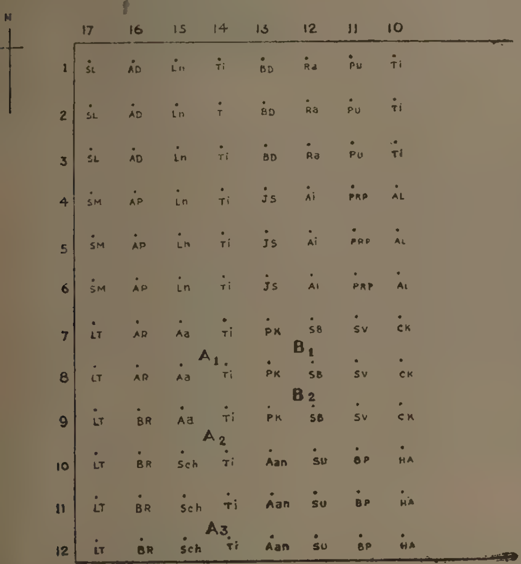
The results of the survey strengthened the hypothesis that black-tip disease of mango is caused by coal fume emitting from brick-kilns. With a view to verify this experiment on the effects of coal smoke on mango fruit were carried out in 1941 and 1942, in one of the orchards (Collection Block) of the Fruit Research Station, Sabour, where no black-tip disease was known to occur and within about three miles of which place there was no brick-kiln. The trees were eight to nine years old, they were healthy and started bearing. They were exposed to fumes by burning coal in improvized ovens [Sen, 1941]. The ovens were constructed with bricks and clay practically in the same fashion in which it is usually done in households. They were 2½ ft. × 3 ft. in size. A rectangular hollow 1 ft. × 1 ft. 3 in. in the middle and an air-passage 1 ft. × 1 ft. next to the ground on one side were left. Iron gratings were inserted in the hollow 1 ft. below the top for holding coal. Improvized domes made from canisters were used as chimneys. When in operation small quantities of fresh coal were added every 20-25 minutes for obtaining a more or less continuous flow of smoke.

Experiments of 1941

Three ovens were constructed at the places marked A_1, A_2 and A_3 in the plan, in Fig. 6, which

* Private communication to the author

hows the part of the orchard in which the experiments were conducted. Distance between the earest tree and an oven was approximately 15 ft. When in operation the smoke could, however, be melt up to about 50 ft. from the ovens in the irection of the wind.



IG. 6. Showing a plan of the part of the mango orchard at the Fruit Research Station, Sabour, in which the experiments on the effect of the coal fume on mango fruit were carried out in 1941 and 1942

Ti = Taimuria, Pk = Pokhraj,
Aa = Aman Abbasi, Sch = Sakerchina
Distance between plants each way = 30 ft.

It was primarily intended in this experiment to tudy the effect on the Taimuria trees Nos. 7 to 12 n row 14 which were exposed to smoke, leaving s control the three trees 1, 2 and 3 on the same ow and belonging to the same variety, situated n the north where the smoke did not reach.

Smoking was started on 11 February 1941 when owers were just opening. To begin with, the reatment consisted of working the ovens once in very four days, for nine hours each day.

Flowers collected from the treated and untreated aimuria trees were gathered during the first week f March and examined under dissecting microcope. No difference was noted. Fruit-set in he two groups of trees, showed no difference. f the treated trees Nos. 7, 9 and 10 and of the ontrols Nos. 2 and 3 had 50 to 60 fruits each on April 1941, others had only a few fruits on hem.

No black-tip effect could be traced until 16 pril 1941 when some fruits on three of the treated trees were suspected to show black spots at their distal ends. At this stage the fruits were about 5 cm. long. On 19 April 1941 some of these fruits were found to have dropped. Careful examination of the drops revealed that their lower ends had also developed a yellowish tinge, but it was not very distinct, as the Taimuria fruit is normally somewhat pale in colour.

The effect did not, however, show any appreciable progress till 26 April 1941. At this stage it was thought probable that the intensity of the treatment was not enough to show a more pronounced effect. From 27 April 1941, therefore, the treatment was intensified by working two of the ovens, A_1 and A_2, every day continuously from 6 A.M. to 5 P.M. At this stage the fruits were about 7 cm. in length.

In another fortnight only three more fruits on one of the trees (No. 7) showed black spots on their tips. The Taimuria fruits did not show much further increase in size during this period. They appeared to have reached their maximum size, being 7 to 8 cm. in length. The intensive treatment, however, tended to have somewhat increased the rate of dropping. On the affected fruits which were still persisting on the tree, it was noticed that the black spots were gradually coalescing and by 22 May 1941 thirteen of the fruits were found to have developed the typical black-tip with patches of dead and dried tissue at the distal ends.

On 10 May 1942 the trees on the adjacent rows, which had fruit on them, were carefully examined and it was discovered that the three Pokhraj trees Nos. 7, 8 and 9 on row 13 situated about 40 ft. from the ovens were showing the characteristic yellowing of the distal ends of many of their fruits. The fruits were approximately 9 cm. in length at the time. On immediate west of the treated Taimuria, there were three Aman Abbasi trees Nos. 7 to 9 on row 15. Only one (tree No. 7) of them had two fruits, both of which, as well, were suspected to show yellowing of their tips. No other trees in the orchard showed any trace of effect. Smoking was stopped on this date.

During the next few days the symptoms were found to steadily progress in Pokhraj fruits. The fruits in these trees were also increasing in size. Some of the fruits had actually become black and dry at the tips and some others showed a blackish tinge, at the very tip, as if emerging from within. In the case of Aman Abbasi no appreciable change was noted. The fruits had eventually dropped.

When it was thought that there was no doubt that the effect noted on Pokhraj trees resembled the typical black-tip damage, on 11 June 1941 smoking was resumed to see if the effect on the fruits could be accelerated by further treatment. The fruits at this stage, however, were considerably advanced

in maturity ; they had reached maximum size, being about 13 to 14 cm. in length. Two of the ovens were shifted and placed at 25 ft. away on the east of Pokhraj trees (Fig. 6, B_1, B_2), as the wind at the time was mostly blowing from that direction. These ovens were worked continuously from 6 A.M. to 5 P.M. every day from 11 to 27 June 1941.

The renewed smoking tended to result into dropping and premature ripening of the fruits, but there was no appreciable increase in the degree of the black-tip effect. No fruit was found to be newly affected. This suggested that the disease may not initiate after the fruit reaches its maximum size. In Table VII are given the number of affected Pokhraj fruits including drops since 11 June 1941. It will be seen from Table VII that the trees show least damage on the fruits on their east sides, i.e. the sides away from the ovens, until the latter were shifted from west to east of the trees on 11 June 1941.

TABLE VII

Effect of ccal smoke on mango fruits

Number of fruits per tree showing effect

Tree / Row No.	East			South			West			North			Total showing no effect	Total showing effect
	No effect	Black-tip	Yellow-tip	No effect	Black-tip	Yellow-tip	No effect	Black-tip	Yellow-tip	No effect	Black-tip	Yellow-tip		
13—7 . .	13	1	3	4	1	..	..	..	..	4	..	3	18	8
13—8 . .	16	1	4	1	2	..	5	2	4	7	2	3	32	18
13—9 . .	22	1	1	14	3	6	2	..	1	4	1	..	42	13

During the period of renewed smoking a record on the heating effect of the ovens on the temperature of the orchard-atmosphere was also noted, during the experiment. Thermometers were hung in clear places where there were no shade from any trees at distances of 5 ft., 25 ft. and 50 ft. from the ovens in all directions. As the majority of the fruits on the trees were within a man's height the thermometers were hung 6 ft. above ground level. Readings on these thermometers and wind directions were noted every two hours from 8 A.M. to 6 P.M. No significant difference in the temperature on any occasion was recorded at 25 ft. and 50 ft. on any side of the ovens. At 5 ft. a small increase was, however, occasionally noted in the direction of the wind ; the maximum increase noted was 2·5° C.

EXPERIMENTS OF 1942

The experiment carried out in 1941 showed that coal smoke causes black-tip disease of the mango. It further indicated that the disease does not initiate after the fruits have attained full size. Two experiments were carried out this year in order firstly to confirm these results, and then to determine the critical stage of the fruit at which the disease initiates, and finally if the disease always different angles, namely, horizontally, or vertically upwards. The experiments were carried out in the same orchard at the Fruit Research Station, Sabour, in which the 1941 experiments were conducted. Flowering and fruiting were in general very poor this year. The three Sakerchina trees Nos. 10, 11 and 12 on row 15 (Fig. 6) were, however, in good cropping. These were, therefore, selected for the work. And smoking this year was done continuously by working the ovens throughout day and night, during the period of treatments.

Experiment 1—The first experiment was conducted on tree No. 10. The method of smoking in improvized ovens as used in the previous year was employed. Three ovens were constructed on the three sides of the tree,—east, west and south, at 15 ft. away from it. The experiment was started on 24 April when the fruits were about 2 to 3 cm. long and appeared to have started fast development in size. Before beginning the smoking treatment sample numbers of fruits on the tree were held at different angles with the help of suitably improvized net bags and tied on to a bamboo frame-work erected round the tree (Plate XIV, fig. 2). Fifty fruits were held with their tips vertically upwards, and 50 with their tips horizontally, 50 fruits were given net bags, but left in

controls. Smoking was done continuously throughout day and night but only one oven was worked at a time according to the direction of the wind, so that the smoke was always made to blow on to the treated tree. In seven days time the fruits began to show the typical yellowing of their tips and on the 10th day, i.e. on 3 May some of them showed initiation of the black-tip. On this date smoking was stopped. At this stage the fruits were 5 to 6 cm. in length. Within the next seven days the disease became so pronounced on the tree that one had to search for a fruit which did not show the symptom. The damage noted is shown in three stages in the bottom row of fig. 1, Plate XIV, in the top row of which are shown comparable cases of black-tip affected fruits of Calcuttia-Bombai mango collected from a brick-kiln area. By this time the fruits had reached their maximum size, 8 to 9 cm. in length. Records taken on the samples of fruits, held with their tips at different positions (Table VIII) show that in whatever position the fruit be held the disease always initiates from its tip. It was also noted that difference in the position of the fruit makes little difference as to the intensity of the damage.

TABLE VIII

Effect of coal smoke on mango fruits

Fruits were held with their apices at different angles, and exposed to smoke during their stages of active development in size—from 24 April to 3 May, 1942—50 fruits treated in each different positions

Positions of fruits	Drops before symptom was first noted on 3 May 1942	Effects as noted between 3 May 1942 when symptom was first noted and 9 June 1942 when the fruits were finally harvested			Fruits showing black-tip effect (black or yellow) as percentage of total number of fruits found in tree between 3 May 1942 and 9 June 1942
	Fruit No.*	No symptom	Yellow-tip	Black-tip	
		Fruit No.	Fruit No.	Fruit No.	per cent
1. Normal without net bag	14	8	7	21	78
2. Normal with net bags	11	6	9	26	85
3. Apex held horizontally with net bags	5	11	4	30	76
4. Apex held vertically upwards with net bags	8	7	7	28	79

* Relatively less drops under 3 and 4 may possibly be due to the fruit-stalks in these cases being supported by sticks for holding the fruits in desired positions

Experiment 2—The treatment of experiment 1 was so controlled that the smoke did not blow on to any other tree, and consequently no other tree showed any sign of the disease. The tree No. 12 which was also a Sakerchina mango was selected for a second experiment. From 14 May 1942, when the fruits had already reached their maximum size, smoke was applied to this tree in the same manner as in the case of experiment 1. The treatment was continued up to 25 May 1942. There were 190 fruits on the tree, none of them showed any indication of the black-tip disease, although the treatment tended to hasten ripening by developing a yellowing of the fruits all over the skin. It also tended to cause dropping of the fruits. The treated fruits when ripe had tough flesh, their taste and flavour also deteriorated.

DISCUSSION

The results presented above conclusively show disease of mango fruits, and that the black-tip damage of the mango crop alleged to be caused by brick kilns working near mango orchards is really caused by the fumes emitting from such kilns.

It appears interesting that the black-tip disease always initiates at the apex and that it is produced only when the fruit is exposed to coal fume during the period of its active development in size. The development of the mango fruit is likely to take place in distinct stages, as is found in other drupecious fruits—at some stages the cells increase in number and at others they enlarge in size, and according to these stages the fruit shows chemical changes in its various tissues [Tukey and Young, 1939]. Further, as would appear clear from the shape of the mango fruit (Plate XIV, fig. 1), the rate of enlargement of the cells at the apex is comparatively less than that of cells at any other part of it. The apical cells are relatively more compact and may, therefore, have higher plasmatic concent-

gases of coal fume and some substance present in the composition of the apical cells of the developing mango fruit. The first visible symptom of the effect is etiolation of the apex of the fruit. This would be the result of plasmolysis and derangement of chloroplasts. It is followed by cell disintegration and decay [Brizi, 1903—c.f. Blakke, 1913]. The toxic reaction makes the dead tissue immune to any organism, it dries up and blackens.

The reaction might be compared to the effect of gas nuisance on human beings and other animals. In them harmful gases are inhaled into the system where it reacts with blood. In plants harmful gas or gases would find their way into the tissues through stomata of leaves [Zimmerman and Crocker, 1934] and lenticels of fruits, although it is possible that the gases may also be absorbed over the surface of the leaf or skin of the fruit. A comparison of the numbers of lenticels per unit area of the skin of a number of varieties of mango, has actually shown that varieties showing greater susceptibility to black-tip damage have relatively larger number of lenticels. Further, lenticels per unit area of the skin, are always more preponderant in the apical region of the fruit than elsewhere (Table IX), as the cells in that part show relatively smaller enlargement in size. It is not, however, considered likely that preponderance of lenticels at the apex is the cause of initiation of the black-tip effect at that point, although it may supplement, to some extent, the conditions determining the effect. If it was not some particular cells, at some particular stage of the fruit, and if cells at any part of the fruit at any of its stages were capable of showing black-tip effect, the symptoms would be expected to appear, at least in time, round lenticels all over the skin.

TABLE IX

Number of lenticels per unit area of skin of different varieties of mango

Unit area is equal to a circular section of 0·9 cm. diameter. The studies were made during the 1st week of May (1942) when fruits were yet growing in size. Five fruits of each variety were taken and on each fruit counts were made in ten unit areas in each of basal, central and apical regions. For each region the average of the 10 readings was taken and the values given below are the means of such averages of the five fruits of each variety.

	Variety	Size of fruit at the time of counting lenticels			Number of lenticels per unit area				Susceptibility to black-tip disease
		Length cm.	Breadth cm.	Thickness. cm.	Basal region	Central region	Apical region	Average of three regions	
Present in a kiln area	Hemsagar	5·6	4·8	4·4	25·2	32·0	46·5	34·6±0·836	Very marked
	Zardalu	7·6	5·0	4·6	16·9	24·5	68·3	36·6±1·262	Do.
	Kadua	12·8	7·7	6·8	10·6	17·1	36·7	21·4±1·095	Less than Hemsagar and Zardalu
	Kumarpahar	9·4	6·4	5·6	8·3	17·2	32·1	19·2±1·867	Do.
	Bharatbhog	9·9	6·2	5·2	11·5	12·9	16·7	13·6±0·715	Less than the above four varieties
	Jalibandha	10·2	7·3	6·5	7·4	9·4	26·8	14·6±1·236	Do.
	Kaitki	6·6	4·3	4·1	7·6	10·0	17·3	11·7±0·858	Do.
	Langra	8·3	6·0	5·0	7·7	5·3	11·3	8·1±0·526	Do.
Experimentally exposed to coal smoke	Sakerchina	7·3	4·9	4·1	9·2	19·4	34·4	21·0±1·229	Marked
	Pokhraj*	..	..	..	..	..	..	22·0	Do.
	Taimuria*	..	..	..	..	..	..	6·0	Much less than Pokhraj and Sakerchina

* Mean number of lenticels per unit area of skin of fruits, average of all different regions, estimated in 1941 by actually counting in 15 circular sections, 5 sections in each of the basal, central and apical regions. The rest of the data were collected in 1942.

Of the coal fume gases sulphur dioxide, ethylene and carbon monoxide have been found to be toxic to plants, and of these the first named is known to be the worst offender [Zimmerman and Crocker, 1934]. It is interesting to note that De [Das Gupta and Verma, 1939], had experimentally reproduced the black-tip effect on mango fruit by burning sulphur under a tree bearing healthy fruits and thus exposing them to SO_2 gas. At the time of fumigation the fruits were about an inch in length, i.e. they were still growing. Sulphur was burnt twice a day, for half-an-hour on each occasion, for seven days. Yellowing of the apices of fruits was visible on the fifth day and blackening

appeared on the seventh day. Das Gupta, Verma and Sinha [1941] treated mango fruits with SO_2 gas in fumigation chambers. They could not reproduce black-tip effect but found small brick-red coloured areas round lenticels all over the skin. Ranjan and Jha [1940] report that they exposed plucked mango fruits in the laboratory to currents of ethylene-air mixture, sulphur dioxide-air mixture and ethylene-sulphur dioxide-air mixture. According to them Sulphur dioxide-air mixture did not show black-tip effect, it turned the skin of the fruit whitish, through bleaching, but ethylene-air and ethylene-sulphur dioxide-air mixtures produced light brown patches which finally turned darker. This they took to be black-tip effect and thought that ethylene was its cause. They do not, however, describe the symptoms in sufficient detail, particularly whether or not the effect initiated at the apex, as is characteristic of the black-tip disease. During the mango season of 1942, the present author carried out three sets of experiments, on their lines, on the effects of ethylene-air mixture on mango fruit. Ethylene-air mixture was found to cause yellowish brown patches here and there on the skin, but there was no indication of the effect initiating only at the apex of the fruit. The patches gradually enlarged and also became darker but they did not resemble the typical black-tip. The typical black-tip resembles a dry rot but these patches developed wet rotting. It is hoped that further studies will throw more light on the mechanism of the black-tip effect.

Summary and conclusion

Survey and experiments have been carried out with a view to come to a definite conclusion as to the cause of the black-tip disease of the mango which is popularly believed to arise from the fumes emitting from coal burning brick-kilns working near orchards.

A survey was first conducted in 1939, five miles round the city of Bhagalpur, Bihar, where there were 38 brick-kilns in 18 centres. The survey was repeated during the next two years, and an intensive examination was made in two kiln areas by studying each and every plant within half a mile round brick-kilns. In addition, the occurrence of brick-kilns in the whole of the province of Bihar and the incidence of black-tip disease were determined. Also information regarding the disease was gathered from the various mango growing Provinces and States of India.

The disease has been found to occur in orchards near operating kilns. Wherever the disease has been noted an operating kiln could be traced in the vicinity.

It has been revealed that mango orchards which produce healthy fruits begin to show the damage as soon as a kiln is started near them. The same orchards recover and produce healthy fruits if the kiln is stopped, the damage reappears if the kiln is made to work again. The damage has been noted in the widely distant mango tracts of Bengal, Bihar, the United Provinces and the Punjab, in orchards near brick-kilns. It is practically unknown in Madras, Mysore, Bombay and Baroda, at the same time it is reported that the modern coal burning brick-kiln (Bull's kiln) is not much in vogue in these regions.

Where the disease occurs it is found most conspicuous, and can also be traced farthest from the kiln, wind-ward. Fruits on the kiln side of the trees show more severe damage than those on the opposite side. Trees situated on a lower level are found much less affected than those on the same level with the kiln. Presence of huge ditches separating kilns and orchards is found to make no difference as to the incidence of the disease.

Trees showing the disease on their fruits are found normal in all other respects. Symptoms of the mango is found to become apparent when the fruit reaches some size. In these studies it was noted earliest by the middle of March when the fruit was about 1 cm. long. No effect could be traced during the flowering stages. Fruit set was normal in trees which later on showed the disease. The time of initiation of the damage was, however, found to be influenced by the distance between kilns and orchards. Within 500 ft. to 600 ft. from kilns the damage was found to become conspicuous by the beginning of April when fruits were 2-3 cm. long. At a distance of over 1,000 ft. the damage was found to initiate, in the same varieties in the same area, two weeks later when the fruits had fairly advanced in size.

Different varieties of mangoes showed difference in the degree of damage. At a certain distance some varieties were found severely damaged, while others showed slight effect and still others escaped the damage altogether. Within 500 ft. to 600 ft. of a kiln, however, all the varieties were found to be affected.

The damage was found to be in inverse rates to the distance of orchards from kilns. The maximum distance up to which damage was actually traced in these surveys is nearly 700 yards. Reports had, however, been received that the disease could be caused even at a much greater distance, when more than one kiln work at one place and wind blows in one direction for a number of days during the mango season. The volume of smoke emitting from one place, the course and velocity of wind, levels on which kilns and orchards are situated, and presence or absence of vegetation or other objects that may act as screens between kilns and orchards, are the factors likely to determine the distance up to which the deleterious effect of kiln fume on mango can reach. Smoke injury is known to extend up to several miles away from the source of smoke [Blakke, 1913 ; Hiksch, 1934 ; Zimmerman & Crocker, 1934 ; and Horicht, 1938]. For all practical purposes, however, mango orchards

about a mile away from brick kilns would appear to be quite safe.

Thickness of skin of the fruits of the different varieties do not show any concomitant relation to their susceptibility to black-tip damage. The varieties which are relatively more susceptible to the injury, however, appear to show larger number of lenticels per unit area of the skin of their fruits than those which are comparatively more resistant to the injury.

Fruits of trees exposed to brick kiln fumes when covered in celophane bags, from the time of their setting, appear to escape the disease.

Fruits on potted plants when exposed to fumes in a kiln area develop symptoms of the disease.

Fruits on healthy trees in an orchard in which black-tip is unknown develop the disease in all its symptoms when experimentally exposed to coal smoke, controls showing no effect.

The disease is initiated only when the fruits are exposed to coal fumes during the active stages of their increase in size. Exposure to coal fumes after the fruits reach maximum size, though yet green, do not produce the black-tip effect. It, however, shows an adverse effect inasmuch as the fruits tend to ripen prematurely and develop toughness of flesh.

In whatever position the fruits are held the disease always initiates at the tips (apices)—fruits hanging normally with their tips downwards, or fruits held vertically upwards, or horizontally show no difference as to the point of initiation of the disease or intensity of its attack.

It is concluded that the black-tip disease of the mango crop is caused by exposure to coal fumes during the stages of active development in size of the fruits. And that the black-tip damage of the mango alleged to be caused by brick-kilns working near orchards is actually caused by the smoke emitting from such kilns.

As regards the mechanism of the black-tip effect of the mango it is suggested that the symptoms are the results of some toxic reaction between certain gas or gases of the coal fumes and some substance present in the tissue of the developing fruit. As to why the disease always initiates at the apex it may be because the cells in that part are relatively more compact and the reacting substance in the fruit is present only there, or present in that part of the fruit at a higher concentration than in other parts. The rate of increase in size of the fruit and the presence of relatively larger number of lenticels at its lower end may also have to play some part in the process.

Sulphur dioxide, ethylene and carbon monoxide are the harmful gases of coal fumes and of these the first named is known to be the greatest offender as regards injury to vegetation. It remains, however, yet to be definitely determined which combustion product or products of coal cause black-tip of the mango, and what is the mechanism of this effect. It is intended to carry out further studies on these lines.

In America, brick-kilns could be made practically smokeless by the installation of certain fixtures to them [Blakke, 1913]. How far it may be feasible to employ such fixtures to the brick-kilns used in this country is a matter which falls into the hands of the engineer. It is, however, possible that his problem may prove easier when it is determined which combustion product of coal causes the black-tip injury of the mango crop. Meanwhile it is suggested that the damage might be reduced (*i*) by restricting sites of new brick-kilns at safe distances from valuable orchards,—about a mile on east and west, and half a mile on north and south would be fairly safe for all practical purposes ; (*ii*) by stopping kilns before the time of fruit-set of the mango, i.e. by the end of February, in areas where they exist near valuable orchards ; and/or (*iii*) by using high chimneys that will dilute the deliterious gases of the smoke coming forth, and make it harmless—telescopic chimneys, about 40 ft. to 50 ft. high, might be used in brick-kilns.

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P. S.—Since the manuscript was prepared experiment on the effect of coal smoke on mango fruit was conducted for the third time during the 1943 mango season confirming the results of 1941 and 1942.

Two Sakerchina trees, Nos. 10 and 11 on row 15, and a Safeda tree, No. 3 on row 17 on the same plot (Fig. 6), as used in the previous years, were employed.

1. *Sakerchina—Row 15, tree 10*—Experiment was started on 26 April 1943 when average size of fruit measured 3·4 cm. in length. Smoking was continuous day and night till experiment was stopped on 15 May 1943. The tree was wholly exposed to smoke from an oven at 15 ft. on the east of the tree. Symptom of black-tip effect was first noted on 4 May 1943 —average size of fruit 5·0 cm. in length. Definite black-tip effect was noted on 15 April 1943. Fruits reached maximum size, average length 6·5 cm. Effect more prominent on the oven side of the tree. Severity of effect was appreciably less towards the opposite side. A final record was taken on 23 May 1943 there were 50 fruits on the tree, 29 of them showed definite black-tip effect, the rest also showed effect inasmuch as they showed general paleness of colour and inhibited growth.

2. *Sakerchina—Row 15, tree 11*—Experiment was started on 28 April 1943 when average size of fruit measured 3·6 cm. in length. Smoking was continuous day and night till experiment was stopped on 15 May 1943. Only one section of the tree, on the east, was exposed to smoke from an oven at 15 ft .on the east of the tree. The rest of the tree was protected by mat screen. Symptom of black-tip effect was first noted on the treated section of the tree on 4 May 1943 ; average size of fruit 5·6 cm. in length. Definite black-tip effect was recorded on 15 May 1943. Average size of the fruits 6·3 cm. in length. A final note was taken on 23 May 1943. There were 50 fruits on the treated section of the tree and of them 33 showed definite black-tip effect, others showed paleness of colour and inhibited growth. Within the treated section it was apparent that the black tip effect was more prominent on the upper part than on the lower part. The chimney of the oven leading out the smoke in this case, was more in a level with the upper part. No black-tip effect as noted on the section of the tree protected by mat screen. The fruits on this part, however, showed paleness of colour and inhibited growth. This effect was, however, more prominent nearer the srceen than farther away from it. The average length of a normally growing Sakerchina measured 7·5 cm. in length.

3. *Safeda—Row 17, tree 3*—Experiment was started on 22 April 1943—average size of fruit 4·0 cm. long. Smoking was continuous day and night from an oven at 15 ft. on the east of the tree. During the first week the tree was wholly exposed to smoke. But on 28 April 1943 when it was found difficult to control smoking of the whole tree due to its relatively large size and irregular wind, only a section of the tree on the side of the oven was separated out with mat screens and treated. No symptom of smoke effect was noted on any part of the tree on this date. The fruit measured 7·0 cm. long. The experiment was stopped on 15 May 1943 when the fruits had reached maximum size—average 10·0 cm. Symptom of black-tip effect was first noted on 4 May 1943 on the treated section of tree when the average size of the fruit was 7·8 cm. long. Definite black-tip effect was recorded on 7 May 1943. Final record was taken on 23 May 1943. There were 80 fruits on the treated section of the tree, 25 of them showed definite black-tip effect, the rest showing general paleness of colour and inhibition of growth. No black-tip effect was noted on the part of the tree that was outside the mat screen, but the fruits showed paleness of colour and somewhat inhibition of growth. This effect was found more prominent on the part of the tree nearest to its treated section and less so on the parts away from it. At the time of starting the experiment, a number of fruits was enclosed in oilpaper bags. Only three bags in the treated section remained intact, the others were damaged by rain and wind. At the end of the experiment it was found that the fruits enclosed in the bags were perfectly healthy showing normal growth and colour.

APPENDIX A

Mango orchards at Manbhara (Bhagalpur) showing their age, directions and minimum and maximum distances from an operating brick-kiln, and varieties present and occurrence of 'black tip' in them

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
1	A1	40	430-860 N.N.W.	9	Bombai 33, Langra 22, Fazli 12, Kumarpahar 2, Golbhadaiya 4, Arhulwa 7, Sundar Prasad 4, Sabaiya 7, Kadua 4, Bijoo 3	98	*Nil*	Fazli, Kumarpahar, Arhulwa, Sunder Prasad, Kadua
2	A4	20	300-750 N.E. .	12	Bombai 17, Langra 3, Fazli 55, Zardalu 11, Golbhadaiya 10, Latra 3, Kadua 1, Kapuria 1, Gulabkhas 1, Homsagar 3, Bharatbhog 14, Kumarpahar 4, Bijoo 8	131	Bombai, Bharatbhog, Zardalu, Golbhadaiya, Kumarpahar, Fazli, Hemsagar, Kapuria, Bijoo	Latra, Gulabkhas, Kadua
3	A5	15	460-860 E. .	5	Bombai 6, Langra 33, Fazli 37, Zardalu 3, Golbhadaiya 4, Bijoo 5	88	Bombai, Fazli .	Zardalu
4	A6	24	600-750 E.N.E.	4	Bombai 2, Fazli 18, Bharatbhog 3, Jalibandha 1	24	Bombai, Bharatbhog	
5	A7	24	720-1050 E.N.E.	8	Bombai 4, Langra 5, Fazli 4, Varatbhog 7, Kumarpahar 2, Jalibandha 2, Rarhivadri 2, Sabaiya 1, Bijoo 1	29	*Nil*	Jalibandha
6	A8	15	660-930 N.N.E.	5	Bombai 1, Langra 8, Fazli 35, Golbhadaiya 4, Kaitki 1, new 1, Bijoo 8	58	*Nil*	Bombai, Langra
7	A9	24	690-1150 N.E. .	8	Bombai 15, Langra 16, Zardalu 4, Golbhadaiya 1, Varatbhog 2, Rohumura 1, Homsagar 6, Gulabkhas 2, Bijoo 4	51	Zardalu, Bombai, Hemsagar, Bijoo	Rohumura
8	A10	20	890-1250 N.E. .	1	Bombai 29	29	*Nil*	
9	A11	25	960-1320 N.N.E.	10	Bombai 7, Langra 8, Fazli 6, Hemsagar 9, Mohanbhog 3, Zardalu 7, Sunder Sah 1, Karailwa 1, Arhulwa 1, Golbhadaiya 2, Bijoo 6	51	Arhulwa	
10	A12	20	1250-1890 N.N.E.	8	Bombai 14, Fazli 5, Gulabkhas 2, Barmasia 1, Varatbhog 1, Sopia 1, Zardalu 6, Alfanso 1, Bijoo 4	35	*Nil*	Baramasia
11	A13	25	1190-1520 N.N.E.	11	Bombai, 20, Langra 21, Fazli 10, Zardalu 4, Varatbhog 10, Sabaiya 2, Golbhadaiya 5, Kadua 2, Arhulwa 1, Hemsagar 1, Dudhia 2, Bijoo 3	81	*Nil*	Hemsagar
12	A14(*a*)	35	960-1350 N. .	5	Langra 23, Fazli 31, Zardalu 14, Varatbhog 9, Golbhadaiya 2, Bijoo 7	86	*Nil*	Golbhadaiya, Bijoo
13	A14(*b*)	35	1290-1550 N. .	6	Fazli 28, Varathbog 7, Hemsagar 6, Kaitki 2, Alfanso 1, Lilkalmi 5	49	Lilkalmi, Hemsagar	Alfanso
14	A15	40	820-1260 E. & E.N.E.	9	Bombai 73, Langra 10, Fazli 7, Zardalu 7, Sabaiya 1, Golbhadaiya 1, Varatbhog 9, Hemsagar 16, Kishunbhog 10	134	Bombai, Hemsagar	Golbhadaiya, Sabaiya
15	A16	15	930-1350 N.E. & E.N.E.	10	Bombai 7, Langra 19, Fazli 17, Varatbhog 1, Alfanso 7, Hemsagar 2, Zardalu 2, Golbhadaiya 2, Gulabkhas 1, Kaitki 1, Bijoo 4	63	Hemsagar . .	Gulabkhas
16	A18	35	1090-1350 N. .	2	Fazli 12, Latra 16, Bijoo 1 . .	29	*Nil*	Latra
17	A19	40	760-1150 N. & N.N.W.	10	Bombai 10, Langra 13, Fazli 22, Kadua 7, Arhulwa 8, Gulabkhas 1, Kumarpahar 11, Golbhadaiya 10, Varatbhog 2, Sabaiya 2, Bijoo 6	92	Kadua	
18	A20(*a*)	>40	1550-2250 E.N.E.	10	Bombai 61, Langra 38, Kadua 1, Kishunbhog 5, Zardalu 4, Gopalbhog 1, Varatbhog 7, Alfanso 2, Hemsagar 2, Golbhadaiya 1	124	*Nil*	Kadua
19	A20(*b*)	>40	2180-2540 E.N.E.	10	Bombai 2, Langra 8, Fazli 25, Zardalu 5, Hemsagar 2, Gulabkhas 5, Kishunbhog 2, Varatbhog 1, Jalsain 1, Rosan Tawak 1, Nakua 2	54	*Nil*	

APPENDIX A—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
20	A21	40	2010-2410 E.N.E.	5	Bombai 4, Langra 5, Fazli 31, Hemsagar 2, Kadua 2, Bijoo 5	49	*Nil*	Kadua
21	A22	>30	2210-2540 E.N.E.	6	Bombai 6, Langra 6, Fazli 18, Varatbhog 1, Kadua 1, Zardalu 1	33	*Nil*	Kadua, Zardalu
22	A23	30	2120-2410 E.N.E.	12	Bombai 5, Langra 7, Fazli 14, Kadua 2, Kaitki 1, Rosan Tawak 1, Dudhia 1, Bharatbhog 3, Jalibandha 1, Karailwa 1, Golbhadaiya 1, Zardalu 1, Bijoo 1	39	*Nil*	Kadua, Karailwa, Zardalu, Golbhadaiya, Bijoo
23	A24(*a*)	40	1850-2210 E.N.E.	9	Bombai 3, Langra 11, Fazli 17, Zardalu 9, Varatbhog 14, Kumarpahar 5, Kaitki 2, Golbhadaiya 2, Jalibandha 1, Bijoo 2	66	*Nil*	Jalibandha
24	A24(*b*)	30	1920-2410 N.E. & E.N.E.	9	Langra 17, Fazli 45, Golbhadaiya 10, Varatbhog 12, Kaitki 5, Jalsain 1, Kumarpahar 1, Bijoo 2, Zardalu 9, Kishunbhog 1	103	*Nil*	
25	A25	20	1680-2080 E.N.E.	12	Bombai 36, Langra 7, Fazil 13, Varatbhog 4, Jalsain 2, Zardalu 6, Jalibandha 1, Kadua 5, Golbhadaiya 1, Kumarpahar 4, Hemsagar 4, Sundershah 1, Bijoo 10	94	*Nil*	
26	A26	10	1320-1750 E.N.E.	12	Bombai 3, Langra 23, Fazli 19, Kaitki 1, Kumarpahar 2, Zardalu 2, Hemsagar 4, Gulabkhas 2, Jalibandha 2, Varatbhog 3, Golbhadaiya 3, Karailwa 1, Bijoo 5	70	Hemsagar	
27	A27	12	1590-2040 N.E.	8	Bombai 14, Langra 27, Fazli 25, Golbhadaiya 5, Varatbhog 7, Zardalu 6, Kishunbhog 2, Gulabkhas 3, Bijoo 16	105	*Nil*	Golbhadaiya
28	A28	40	1050-1880 E.N.E.	17	Bombai 5, Langra 6, Fazli 28, Mohanbhog 2, Kumarpahar 4, Chauria 2, Hemsagar 1, Alfanso 2, Kadua 1, Karailwa 1, Varatbhog 14, Kaitki 2, Kishunbhog 1, Zardalu 2, Golbhadaiya 5, Arhulwa 1, Latra 1, Bijoo 4	82	*Nil*	Latra, Hemsagar
29	A29(*a*)	15	1750-2080 N.E.	4	Langra 24, Fazli 17, Golbhadaiya 1, Gulabkhas 1, New 2, Bijoo 1	46	*Nil*	
30	A29(*b*)	15	1950-2250 N.E.	2	Langra 7, Fazli 2, New 1, Bijoo 6 .	16	*Nil*	
31	A30	>30	1920-2310 N.E.	4	Bombai 1, Langra 1, Fazli 53, Karailwa 1, Bijoo 1	57	*Nil*	Bijoo
32	A31	>30	2180-2640 N.E.	5	Langra 5, Fazli 17, Varathbog 2, Zardalu 2, Arhulwa 1, New 40, Bijoo 7	74	*Nil*	
33	A32	20	2100-2470 N.E. & N.N.E.	6	Langra 10, Fazli 10, Golbhadaiya 2, Varatbhog 7, Kishunbhog 2, Zardalu 5	36	*Nil*	
34	A33	40	2110-2410 N.N.E.	5	Bombai 2, Langra 7, Fazli 10, Kadua 1, Kumarpahar 1, New 1, Bijoo 2	24	*Nil*	
35	A34	25	1980-2180 N.N.E.	8	Bombai 6, Langra 8, Fazli 74, Golbhadaiya 4, Jalsain 2, Zardalu 1, Varatbhog 1, Hemsagar 1, Bijoo 1	38	*Nil*	
36	A35	10	1750-2040 N.N.E.	7	Bombai 5, Langra 10, Fazli 18, Kumarpahar 1, Hemsagar 2, Golbhadaiya 1, Karailwa 2, Bijoo 7	46	*Nil*	Hemsagar
37	A36	30	1920-2370 N.N.E.	12	Bombai 25, Langra 12, Fazli 30, Kaitki 7, Sukul 1, Varatbhog 6, Kishunbhog 4, Soniapaduka 1, Zardalu 8, Golbhadaiya 2, Kumarpahar 1, Lamba Vadri 1	98	*Nil*	Gobhadaiya

APPENDIX A—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
38	A37	>40	1450-1880 N.E. & N.N.E.	10	Bombai 21, Langra 10, Fazli 35, Varatbhog 13, Zardalu 8, Golbhadaiya 2, Kishunbhog 3, Jalibandha 3, Gulabkhas 1, Sabaiya 2, Bijoo 11	109	*Nil*	Gulabkhas
39	A38	40	1550-1950 N.N.E.	12	Bombai 6, Langra 3, Fazli 3, Hemsagar 7, Kumarpahar 2, Golbhadaiya 1, Mohanbhog 1, Kishunbhog 2, Varatbhog 5, Kaitki 2, Zardalu 6, Jalsain 3, Bijoo 3	44	*Nil*	Golbhadaiya, Jalsian
40	A39	45	1480-1920 N.N.E.	..	Bijoo 41	41	*Nil*	
41	A40	45	1320-2280 N. & N.N.E.	15	Bombai 128, Langra 40, Fazli 1, Arhulwa 10, Zardalu 3, Bharatbhog 23, Jalsain 21, Sabaiya 9, Golbhadaiya 5, Nakua 10, Kumarpahar 1, Mohanbhog 1, Dudhia 2, Sunder Prasad 1, Kishunbhog 1, Bijoo 21	277	*Nil*	
42	A41	8	1290-1850 N.E.	4	Bombai 2, Langra 5, Golbhadaiya 2, Hemsagar 1, Bijoo 1	11	*Nil*	Hemsagar, Bijoo
43	A42	30	1190-1520 N.E.	6	Langra 1, Fazli 1, Varatbhog 4, Kumarpahar 3, Zardalu 3, Kaitki 8, Unknown 2, Bijoo 1	23	*Nil*	
44	A43(*a*)	40	1520-1880 N. .	..	Bijoo 53	53	*Nil*	
45	A43(*b*)	50	1650-2140 N. & N.N.W.	..	Bijoo 77	77	Bijoo	
46	A44(*a*)	40	1850-2210 N. .	1	Fazli 88, Bijoo 2	90	*Nil*	
47	A44(*b*)	40	1980-2280 N. .	1	Fazli 52, Bijoo 1	53	*Nil*	
48	A45	45	2010-2540 N. .	2	Fazli 30, Zardalu 1, Bijoo 2 . .	33	*Nil*	Zardalu
49	B1	30	430-690 S.S.W.	8	Bombai 5, Langra 22, Fazli 24, Zardalu 3, Hemsagar 3, Kaitki 6, Golbhadaiya 5, Gulabkhas 5, New 1, Bijoo 3	77	Bombai, Hemsagar Zardalu, Fazli	
50	B2	15	200-530 S.S.W., S.W., & W.S.W.	7	Bombai 9, Fazli 1, Golbhadaiya 3, Kaitki 1, Jalibandha 2, Jalsain 1, Hemsagar 2, Bijoo 6, New 3	28	Bombai, Golbhadaiya, Jalsain, Hemsagar, Jalibandha, Kaitki, Fazli, Bijoo	
51	B3	>40	440-690 S. .	..	New 1, Bijoo 10	11	*Nil*	
52	B4	15	30-500 S., S.S.E. & S.E.	1	Zardalu 1, New 7, Bijoo 18 . .	26	Zardalu, Bijoo	
53	B5	8	2130-2410 W.S.W.	3	Langra 9, Fazli 44, Golbhadaiya 1, Kadua 1, New 1, Bijoo 4	60	*Nil*	Golbhadaiya, Bijoo
54	B6(*a*)	>30	1320-2110 S.W. & W.S.W.	20	Bombai 134, Langra 11, Fazli 41, Lambabhadri 6, Totapari 1, Golbhadaiya 6, Kapuri 2, Sabaiya 3, Kadua 3, Jalsain 2, Jalibandha 4, Hirasonia 2, Dilsaj 1, Kumarpahar 2, Varatbhog 1, Golabkhas 1, Sunder Prasad 1, Barmasia 3, Mithua 1, Kaitki 1	226	Bombai, Lambabhadri	
55	B6(*b*)	30	1850-2580 S.W. & W.S.W.	11	Bombai 80, Langra 18, Fazli 235, Zardalu 3, Varatbhog 4, Kumarpahar 80, Sabaiya 3, Golbhadaiya 13, Kaitki 7, Lambabhadri 2, Jalibandha 1	446	*Nil*	
56	B6(*c*)	30	1950-2180 S.S.W.	2	Bombai 1, Fazli 34	35	*Nil*	
57	B7	30	1190-1650 S.W.	11	Bombai 15, Langra 34, Fazli 117, Kumarpahar 2, Golbhadaiya 2, Zardalu 3, Sabaiya 10, Varatbhog 3, Arhulwa 2, Kadua 1, Bijoo 1	190	Fazli, Arhulwa, Kadua.	

APPENDIX A—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
58	B8	30	1480-1950 S.W.	9	Langra 5, Fazli 15, Hemsagar 33, Dudhia 5, Darma 2, Sukul 38, Kaitki 3, Golbhadaiya 5, Mithua 1	109	Hemsagar, Darma	
59	B9	20	1420-1950 S.S.W.	10	Bombai 14, Langra 28, Fazli 9, Golbhadaiya 10, Zardalu 14, Lambabhadri 6, Varatbhog 10, Dudhia 1, Kishunbhog 15, Gulabkhas 9	116	Lambabhadri	
60	B10	30	1750-2130 S.S.W.	6	Bombai 1, Langra 31, Fazli 36, Rosan Tawak 2, Golbhadaiya 8, Varatbhog 9, Bijoo 4	91	*Nil*	
61	B11	10	860-1020 S.W. .	3	Langra 8, Fazli 1, Varatbhog 1 .	10	*Nil*	Fazli
62	B12	10	990-1220 S.W. .	3	Langra 21, Fazli 9, Golbhadaiya 1, New 1	32	*Nil*	
63	B13	10	1190-1450 S.S.W.	2	Langra 3, Fazli 31, Bijoo 2, New 24	60	*Nil*	Langra, Bijoo
64	B14	30	1350-1980 S. & S.S.W.	15	Bombai 18, Langra 46, Fazli 81, Zardalu 33, Hemsagar 9, Gulabkhas 3, Sukul 1, Kumarpahar 2, Kishunbhog 2, Varatbhog 1, Banka 2, Jalibandha 6, Kaitki 2, Golbhadaiya 1, Sepia 1, Bijoo 16	224	Hemsagar . .	Jalibandha, Sepia
65	B15	4 to 6	720-1380 S.S.W.	10	Bombai 81, Langra 150, Fazli 64, Zaradalu 13, Varatbhog 6, Hemsagar 7, Kaitki 17, Sukul 2, Gulabkhas 17, Golbhadaiya 5, Bijoo 34, New 47	443	*Nil*	
66	C1	30	560-890 W.S.W. & S.W.	. .	Bijoo 2	2	Bijoo	
67	C2	30	490-760 W. & W.S.W.	1	Bombai 1, Bijoo 21 . . .	22	Bombai, Bijoo	
68	C3	40	890-1380 W.S.W.	5	Bombai 8, Langra 3, Fazli 23, Zardalu 5, Varatbhog 1, Bijoo 13	53	Zardalu, Varatbhog	Bombai
69	C4	15	820-1020 W. .	2	Langra 4, Kaitki 12 . . .	16	*Nil*	
70	C5	35	990-1320 W. & W.N.W.	10	Bombai 20, Langra 19, Fazli 46, Golbhadaiya 2, Hemsagar 10, Chauria 2, Varatbhog 1, Kishunbhog 2, Zardalu 1, Kadua 1, Bijoo 5	109	Bombai, Hemsagar, Kishunbhog	Kadua
71	C6	40	790-1320 N.W..	14	Bombai 2, Langra 11, Fazli 110, Kadua 1, Kishunbhog 5, Varatbhog 4, Zardalu 9, Golbhadaiya 5, Alfanso 1, Gulabkhas 2, Chorya 2, Hemsagar 2, Jalibandha 1, Lilkalmi 1, Bijoo 20	176	Lilkalmi, Bijoo .	Hemsagar
72	C7	40	1090-1680 N.N.W.	8	Bombai 6, Langra 7, Fazli 82, Kaitki 2, Lilkalmi 3, Hemsagar 4, Varatbhog 3, Zardalu 4, Bijoo 18	129	Langra, Lilkalmi	
73	C8	40	1290-1550 W. & W.N.W.	8	Bombai 1, Langra 6, Fazli 23, Varatbhog 3, Zardalu 2, Sabaiya 1, Kumarpahar 1, Jalsain 1, Bijoo 1, New 24	63	*Nil*	Zardalu, Jalsalu
74	C10	25	1620-1850 W. .	8	Bombai 10, Langra 25, Fazli 16, Zardalu 2, Jalsain 1, Kumarpahar 1, Dudhia 1, Varatbhog 2, Bijoo 5	63	Bombai, Jalsain	
75	C11	10	1590-1810 W. .	4	Bombai 2, Langra 3, Fazli 4, Hemsagar 5, New 2	16	Bombai, Hemsagar	Fazli
76	C12	15	1550-1920 W.N.W.	6	Bombai 1, Langra 12, Fazli 1, Hemsagar 8, Arhulwa 1, Kumarpahar 2, New 1	26	Hemsagar . .	Bombai, Fazli
77	C13	>30	1590-1920 N.N.W.	7	Bombai 2, Fazli 19, Kishunbhog 2, Golbhadaiya 2, Zardalu 2, Kadua 2, Kaitki 10, Bijoo 4	43	*Nil*	Bombai, Zardalu Kadua

APPENDIX A—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
78	C14	12	1650-2210 N.W. & N.N.W.	5	Bombai 11, Langra 41, Fazli 22, Kaitki 3, Zardalu 9, Unknown 2, New 7, Bijoo 3	98	*Nil*	Langra, Kaitki, Zardalu
79	C15	10	1450-1780 N.N.W.	3	Bombai 1, Langra 9, Fazli 1, New 4	15	*Nil*	Bombai, Langra, Fazli
80	C16	..	1420-1850 N.W.	..	New plants, 64	64	..	
81	C17	>40	2010-2210 N.W.	1	Fazli 1, Bijoo 8	9	*Nil*	Fazli
82	C18	>20	2040-2310 N.W.	6	Bombai 6, Langra 7, Fazli 20, Chorya 1, Hemsagar 1, Zardalu 1, Bijoo 1	37	*Nil*	Zardalu
83	C19(*a*)	40	1810-2280 N.W. & W.N.W.	5	Bombai 2, Langra 22, Fazli 2, Kumarpahar 2, Sabaiya 3, Bijoo 31	62	*Nil*	Fazli, Sabaiya
84	C19(*b*)	12	1650-2140 N.W. & W.N.W.	7	Bombai 29, Langra 11, Fazli 6, Zardalu 3, Varatbhog 1, Kaitki 1, Hemsagar 6, Biju 3	60	*Nil*	Varatbhog
85	C20	10	1590-1950 W.N.W.	4	Bombai 5, Fazli 2, Varatbhog 2, Lilkalmi 2, Bijoo 9	20	*Nil*	
86	D1	25	2080-2470 S.E.	14	Bombai 26, Langra 7, Fazli 45, Kishunbhog 3, Kapuri 1, Hemsagar 6, Zardalu 6, Gulabkhas 1, Jalibandha 2, Kumarpahar 3, Sabaiya 1, Golbhadaiya 3, Pansera 1, Kaitki 1	106	*Nil*	Golbhadaiya, Sabaiya, Kaitki
87	D2	30	1980-2210 S.E.	5	Bombai 32, Langra 1, Fazli 2, Zardalu 2, Golbhadaiya 1	38	*Nil*	
88	D3	35	1920-2130 S.E.	3	Bombai 2, Fazli 3, Zardalu 1, Bijoo 9	15	*Nil*	
89	D4	30	1810-2080 S.E.	1	Fazli 11, Bijoo 3	14	*Nil*	
90	D5	5	1710-1880 S.E.	5	Bombai 5, Langra 12, Fazli 7, Hemsagar 2, Gulabkhas 1, Bijoo 3	30	*Nil*	Bombai, Fazli, Gulabkhas
91	F1	35	330-890 S.S.E., S.E. & E.S.E.	15	Bombai 7, Langra 48, Fazli 83, Zardalu 4, Banka 3, Varatbhog 4, Golbhadaiya 11, Gulabkhas 6, Kumarpahar 2, Kapuri 2, Sukul 3, Kishunbhog 2, Husan Arra 3, Kaitki 3, Brindaban 2, New 6, Bijoo 13	202	Bombai, Zardalu, Langra, Banka, Golbhadaiya, Golabkhas, Bharatbhog, Bijoo	
92	F2	30	760-1050 S.E.	6	Langra 8, Fazli 2, Hemsagar 6, Kachmahua 1, Zardalu 2, Totapari 1	20	Hemsagar	
93	F3	25	660-930 E.S.E.	6	Bombai 5, Langra 1, Fazli 27, Kishunbhog 4, Golbhadaiya 6, Bharatbhog 2, Bijoo 6	51	Bombai	
94	F4	30	860-1190 E.S.E.	10	Bombai 11, Langra 10, Fazli 18, Kishunbhog 2, Varatbhog 4, Golbhadaiya 6, Kadua 4, Zardalu 2, Arhulwa 1, Sabaiya 1, New 4	63	Bombai, Kadua, Arhulwa, Zardalu	
95	F5	30	1120-1350 E.S.E.	2	Langra 6, Fazli 2	8	*Nil*	
96	F6(*a*)	30	1090-1290 E.S.E.	1	Fazli 10, Biju 3	13	*Nil*	
97	F6(*b*)	..	1050-1260 E.	..	New plants 54	54	..	
98	F7	25	1090-1380 E. & E.N.E.	12	Bombai 22, Langra 12, Fazli 10, Varatbhog 1, Gulabkhas 2, Soniapaduka 2, Hemsagar 1, Mohanbhog 1, Jalsain 1, Kadua 1, Golbhadaiya 5, Zardalu 2, Unknown 2, Bijoo 4	66	*Nil*	Fazli, Hemsagar, Kadua
99	F8	35	1260-1550 E.S.E.	11	Bombai 24, Langra 1, Kishunbhog 5, Golbhadaiya 2, Jalsain 3, Hemsagar 9, Karailwa 1, Zardalu 4, Arhulwa 1, Kachmahua 1, Kumarpahar 1, Bijoo 10	62	Hemsagar, Bijoo	
100	F9	35	1260-1480 E.	7	Bombai 1, Langra 19, Fazli 4, Kumarpahar 10, Hirasonia 1, Jalibandha 1, Sundershah 2, Bijoo 1	39	*Nil*	Bombai, Hirasonia

APPENDIX A—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varities	Number of trees in each variety	Total number of trees	Black-tip	No fruits
101	F10	35	1260-1520 E.	2	Fazli 12, Sugapunthi 2	14	*Nil*	
102	F11	35	1260-1650 E. & E.N.E.	26	Bombai 3, Fazli 6, Mohanbhog 2, Kumarpahar 6, Sepia 1, Karailwa 6, Jalibandha 2, Ladua 1, Sukul 6, Sunder Prasad 1, Pansera 2, Jafar Kaitki 3, Jalsain 3, Soniapaduka 1, Nakua 3, Ghrit Nona 1, Lambabhadri 1, Sundershah 3, Rosan Tawak, 2; Golbhadaiya 2, Hira Sonia 2, Kadua 2, Kachmahua 1, Varatbhog 1, Darma 2, Mithua 3, Unknown 2, Bijoo 3	71	Kadua	Bombai, Ladua, Pansera, Jaliandha, Sunder-Prasad
103	F12	40	1480-1950 E. & E.S.E.	9	Bombai 22, Langra 25, Fazli 81, Golbhadaiya 9, Gulabkhas 7, Kumarpahar 2, Zardalu 5, Jalsain 2, Hemsagar 1, Bijoo 1	155	Hemsagar	
104	F13	25	1920-2040 E. & E.S.E.	8	Bombai 9, Langra 17, Fazli 22, Golbhadaiya 19, Zardalu 4, Hemsagar 9, Varatbhog 1, Gulabkhas 2, Bijoo 5	88	Hemsagar	
105	F14	..	2010-2080 E. & E.S.E.	..	New plants 42	42	..	..
106	F15	10	1520-1880 E.	6	Bombai 6, Langra 7, Fazli 21, Zardalu 2, Hemsagar 6, Golbhadaiya 2, Bijoo 2	46	Hemsagar	Zardalu
107	F16	..	1520-1880 E.	1	New plants of Langra 36	36	..	..
108	F17	10	1550-1920 E.	1	Fazli 38, Bijoo 2	40	*Nil*	Bijoo
109	F18	12	1880-2110 E.	5	Bombai 10, Langra 14, Fazli 18, Zardalu 4, Gulabkhas 1, Bijoo 4	51	*Nil*	
110	F19	12	2040-2340 E.	8	Bombai, 6; Langra 11, Fazli 23, Golbhadaiya 13, Lambabhadri 2, Gulabkhas 3, Hemsagar 8, Zardalu 2, Bijoo 1	69	Hemsagar	Bijoo
111	F20	..	1880-1950 E.	..	New plants 8	8	..	..
112	F21	..	2110-2370 E.	..	New plants 24	24	..	..
113	F22	25	860-1320 S.E.	4	Langra 2, Fazli 7, Golbhadaiya 2, Kumarpahar 6, Bijoo 23	40	*Nil*	
114	F23	25	1290-1550 S.E. & E.S.E.	5	Bombai 1, Langra 7, Fazli 8, Darma 1, Golbhadaiya 1, Bijoo 8, New 13	39	*Nil*	
115	F25	30	2470-2770 S.E.	3	Langra 6, Fazli 22, Mithua 1, Bijoo 1	30	*Nil*	Langra
116	F26	20	2740-3000 S.E.	11	Bombai 1, Fazli 8, Paraitha 3, Kumarpahar 2, Husan Ara 2, Mithua 1, Zardalu 1, Jalsain 1, Champa Kelwa 1, Sabaiya 1, Hemsagar 2, Bijoo 1	24	*Nil*	Zardalu, Hemsagar, Sabaiya, Bijoo
117	F27	5	2140-1610 E.S.E.	6	Bombai 11, Langra 24, Fazli 29, Zardalu 2, Hemsagar 1, Gulabkhas 2, Bijoo 3	72	*Nil*	Bombai, Zardalu, Bijoo
118	F28	30	2580-3030 S.E.	23	Bombai 20, Langra 14, Fazli 53, Hemsagar 8, Kumarpahar 7, Gulabkhas 3, Karailwa 2, Zardalu 4, Jalsain 2, Golbhadaiya 2, Kishunbhog 4, Sukul 5, Sepia 1, Soniapaduka 1, Sabaiya 1, Jafar Kaitki 3, Kapuri 1, Kachmahua 1, Mithua 3, Husna Ara 1, Lamba Vadri 1, Varatbhog 2, Pansera 1, Bijoo 6	146	*Nil*	Soniapaduka, Kachmahua, Pansera
119	J1	20	2240-2910 S.E.	8	Bombai 60, Langra 7, Fazli 64, Varatbhog 12, Golbhadaiya 23, Gulabkhas 2, Hemsagar 9, Zardalu 3, Bijoo 2	182	*Nil*	Bombai, Hemsagar, Zardalu, Gulabkhas, Bijoo
120	J2	30	2060-2370 S.E. & S.S.E.	8	Bombai 9, Langra 17, Fazli 28, Varatbhog 11, Sabaiya 4, Golbhadaiya 6, Jalsain 1, Arhulwa 2, Bijoo 1	79	*Nil*	
121	J3	25	2250-2610 S.S.E.	8	Bombai 25, Langra 20, Fazli 18, Golbhadaiya 2, Lamba Vadri 5, Kishunbhog 1, Zardalu 1, Hemsagar 2	79	*Nil*	

Appendix B

Mango orchards at Laluchak (Bhagalpur) showing their age, directions and minimum and maximum distances from an operating brick-kiln, and varieties present and occurrence of 'black tip' in them

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
1	A1	40	160-460 E.S.E. & S.E.	5	Bombai 1, Langra 3, Fazli 7, Zardalu 1, Golbhadaiya 1, Bijoo 2	15	Zardalu, Fazli .	Bombai, Golbhadaiya, Bijoo
2	A2	50	200-600 S.S.E. & S.E.	..	Bijoo 57	57	Bijoo . .	..
3	A3	40	200-490 W. & W.S.W.	3	Bombai 16, Langra 5, Fazli 4, Bijoo 3.	28	Bombai, Bijoo, Langra.	..
4	A4	50	330-990 W.S.W. & S.W.	6	Bombai 5, Langra 3, Fazli 11, Zardalu 7, Hemsagar 1, Golbhadaiya 4, Bijoo 1	32	Zardalu, Hemsagar, Golbhadaiya, Bombai.	Langra & Bijoo.
5	A5	45	1320-1750 S. .	22	Bombai 32, Langra 10, Fazli 13, Kachmahua 1, Sonia 1, Kishunbhog 2, Soniapaduka 3, Arhulwa 1, Jalibandha 3, Zardalu 4, Barmasia 1, Lamba Vadri 2, Dudhia 1, Jarukhra 1, Dhumnaha 1, Lohajung 1, Sabaiya 2, Mohanbhog 1, Dilsaj 1, Champa 1, Varatbhog 4, Gulbhadaiya 3, Bijoo 2	91	*Nil.*	Kachmahua, Barmasia, Dumnaha, Lohajung, Sabaiya
6	B1	45	1050-1550 N.N.W. & N.W.	7	Bombai 5, Langra 9, Fazli 5, Soniapaduka 1, Sabaiya 1, Jalibandha 1, Zardalu 1, Unknown 1, Bijoo 5	29	*Nil.*	
7	B2	40	1150-1590 N.N.W. & N.W.	7	Bombai 4, Langra 2, Fazli 7, Jalibandha 2, Soniapaduka 2, Sabaiya 1, Bharatbhog 2, Bijoo 3	23	*Nil.*	Jalibandha
8	B3	40	1380-1780 N.N.W.	8	Bombai 5, Langra 8, Fazli 5, Kumarpahar 1, Soniapaduka 4, Sabaiya 1, Mandraji 2, Varatbhog 1, Bijoo 4	31	*Nil.*	Bombai, Fazli
9	B4	>30	1620-1810 N.W. & N.N.W.	3	Bombai 2, Langra 2, Fazli 1 . .	5	*Nil.*	Langra, Fazli.
10	B5	>20	1350-1650 N.W. & N.N.W.	9	Bombai 11, Langra 5, Fazli 17, Mohanbhog 1, Jalibandha 1, Golbhadhaiya 1, Zardalu 2, Kishunbhog 1, Sabaiya 2, Bijoo 18	49	*Nil.*	Sabaiya, Jalibandha
11	B6	30	1450-1710 N.W.	1	Fazli 1, Bijoo 7	8	*Nil*	
12	B7	40	890-1020 N.N.W.	3	Bombai 4, Langra 6, Zardalu 1, Bijoo 1	12	*Nil*	
13	B8	..	610-760 N.W. .	3	Bombai 2, Langra 3, Fazli 3, Bijoo 1	9	*Nil*	Bombai, Langra, Fazli, Bijoo
14	B9	30	430-790 N.N.W.	9	Bombai 2, Langra 9, Fazli 47, Kumarpahar 2, Dilsaj 5, Jalibandha 4, Karailwa 2, Golbhadaiya 2, Kadua 1, Bijoo 4.	78	*Nil*	Kumarpahar, Jalibandha, Kadua.
15	B10	30	660-1090 N.N.W.	12	Langra 19, Fazli 20, Kishunbhog 14, Jalibandha 6, Hemsagar 5, Varatbhog 3, Soniapaduka 2, Sabaiya 1, Golbhadaiya 1, Mohanbhog 1, Zardalu 1, Sepia 2, Bijoo 15	90	*Nil*	Sabaiya, Golbhadaiya, Zardalu.
16	B11	>30	930-1210 N. .	8	Bombai 17, Langra 1, Fazli 16, Jalibandha 2, Khirsapat 1, Soniapaduka 1, Golbhadaiya 1, Dilsaj 1, Bijoo 1	41	*Nil*	Langra, Jalibandha, Khirsapat, Bijoo, Soniapaduka
17	B12	>30	990-1260 N. .	8	Bombai 16, Langra 5, Fazli 16, Varatbhog 1, Kishunbhog 1, Kumarpahar 1, Jalibandha 1, Darma 1, Unknown 1	43	*Nil*	Jalibandha
18	B13	>30	1020-1320 N. & N.N.W.	8	Bombai 15, Langra 5, Fazli 11, Dudhia 1, Jalibandha 3, Soniapaduka 2, Sabaiya 2, Kishanbhog 2	41	*Nil*	Jalibandha, Sabaiya

APPENDIX B—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maxium distances (in ft.) and directions from an operating brick-kiln	Number of Varieties.	Number of trees in each variety	Total number of trees	Black-tip	No fruits
19	B14	50	1150-1480 N.N.W.	..	Bijoo 38	38	*Nil*	
20	B15	25	1290-1570 N.N.W.	10	Bombai 11, Langra 5, Fazli 4, Sabaiya 3, Jalibandha 3, Kumarpahar 1, Arhulwa 2, Hirasonea 1, Soniapaduka 1, Kadua 1, Bijoo 6	38	*Nil*	Langra, Fazli, Jalibandha, Bijoo
21	B16	>50	1480-1750 N.N.W.	..	Bijoo 3	3	*Nil*	Bijoo
22	B17	>30	540-760 N. .	2	Langra 16, Zardalu 1, Bijoo 3 .	20	*Nil*	
23	B18	50	600-760 N.N.E.	..	Bijoo 15	15	*Nil*	
24	B19	>40	530-760 N. & N.N.E.	1	Bombai 1, Bijoo 16 . . .	17	*Nil*	
25	B20	50	430-610 N. & N.N.E.	1	Langra 1, Bijoo 58 . . .	59	*Nil*	
26	B21	15	720-1020 N. & N.N.E.	..	Bijoo 26	26	*Nil*	
27	B22	4	720-1020 N. .	1	Langra 36	36	*Nil*	Langra
28	B23	20	930-1580 N. .	5	Bombai 8, Langra 23, Fazli 7, Zardalu 5, Gulabkhas 2	45	*Nil*	Bombai
29	B24	25	720-960 N. .	9	Bombai 3, Langra 5, Fazli 17, Jalibandha 6, Sabaiya 3, Kumarpahar 1, Dilsaj 2, Hemsagar 2, Mohanbhog 1, Bijoo 8	48	*Nil*	Fazli, Jalibandha, Sabaiya, Kumarpahar, Bijoo
30	B25	30	940-1650 N.N.E.	18	Bombai 4, Langra 17, Fazli 25, Lamba-Vadri 3, Gulabkhas 1, Zardalu 5, Golabhadaiya 1, Jalibandha 2, Kumarpahar 1, Sabaiya 1, Karelwa 2, Arhulwa 1, Dudhia 1, Dilsaj 1, Darma 1, Kishunbhog 3, Soniapaduka 2, Chauria 1, Bijoo 13	85	*Nil*	Sabaiya, Karelwa, Kumarpahar, Jalibandha
31	B26	60	1190-1650 N. & N.N.E.	..	Bijoo 11	11	*Nil*	
32	B27	35	1620-1810 N. & N.N.E.	14	Bombai 22, Langra 12, Fazli 20, Soniapaduka 18, Sabaiya 7, Barmasia 1, Arhulwa 5, Kishunbhog 5, Golbhadaiya 1, Zardalu 4, Jalibandha 1, Banka 1, Karelwa 1, Hemsagar 2, Bijoo 6	106	*Nil*	Soniapaduka, Jalibandha, Barmasia, Bijoo
33	B28	35	1590-1850 N.N.E.	8	Bombai 1, Langra 5, Fazli 24, Kumarpahar 1, Kaitki 2, Kishunbhog 1, Hemsagar 2, Zardalu 1, Bijoo 15	52	*Nil*	Bombai, Langra, Fazli, Kumarpahar, Zardalu
34	B29	30	1850-1980 N.E.	..	Bijoo 16	16	*Nil*	
35	B30	45	1950-2210 N. .	..	Bijoo 27	27	*Nil*	Bijoo
36	B31	40	390-980 N.W., N.N.W., N. & N.N.E.	14	Bombai 18, Langra 29, Fazli 15, Kishunbhog 5, Zardalu 4, Arhulwa 3, Soniapaduka 3, Varatbhog 2, Kumarpahar 2, Dilsaj 2, Sabaiya 1, Golbhadaiya 2, Hemsagar 1, Kadua 1, Bijoo 6	94	Bombai, Kadua .	Sabaiya, Hemsagar
37	B32	30	600-720 N.N.E.	4	Langra 6, Fazli 9, Karelwa 1, Varatbhog 1, Bijoo 18	35	*Nil*	Fazli, Varatbhog
38	B33	30	720-860 N.N.E.	4	Bombai 1, Langra 1, Fazli 11, Barmasia 1, Bijoo 5	19	*Nil*	Langra, Barmasia, Fazli, Bijoo
39	B34	40	860-1190 N.N.E.	..	Bijoo 42	42	*Nil*	
40	B35	40	860-1020 N.N.E.	..	Bijoo 27	27	*Nil*	
41	B36 (a & b)	40	860-1260 N.N.E.	..	Bijoo 166	166	*Nil*	
42	B37	50	1120-1320 N.E.	..	Bijoo 65	65	*Nil*	
43	B38	30	660-1020 N.E. .	8	Langra 4, Fazli 23, Jalibandha 9, Golbhadaiya 3, Hemsagar 3, Sukul 3, Kumarpahar 2, Sabaiya 1	48	*Nil*	Sabaiya, Kumarpahar, Langra, Bombai.

APPENDIX B—*contd*.

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in. ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
44	B39	25	1020-1190 N.N.E.	8	Bombai 1, Langra 3, Fazli 15, Gulabkhas 2, Jalibandha 1, Golbhadaiya 1, Kumarpahar 6, Karelwa 1, new 20, Bijoo 3	53	*Nil*	Langra, Fazli, Karelwa, Jalibandha, new
45	B40	25	1220-1480 N.E.	18	Bombai 20, Langra 5, Fazli 7, Zardalu 2, Varatbhog 2, Kishunbhog 2, Banka 1, Gulabkhas 1, Alfanso 1, Sukul 2, Soniapaduka 1, Sabaiya 1, Mohanbhog 1, Mandrasi 1, Golbhadaiya 3, Dilsaj 1, Dudhia 2, Kadua 2, Bijoo 3	58	*Nil*	Fazli, Gulabkhas, Alfanso, Sabaiya, Mandraji
46	B41	30	1380-1620 N. E.	6	Bombai 2, Langra 1, Fazli 35, Golbhadaiya 2, Gulabkhas 1, Tutia 1, new 16, Bijoo 1	59	*Nil*	Langra, Tutia, new
47	B42	25	1190-1750 N.N.	7	Bombai 17, Langra 25, Fazli 13, Zardalu 16 ; Jalibandha 1, Lambabhadri 3, Sabaiya 1, new 22, Bijoo 2	100	*Nil*	Fazli, Jalibandha, Bijoo, new
48	B43	40	1480-1920 N.E.	12	Bombai 5, Langra 24, Fazli 32, Karelwa 2, Hemsagar 1, Gulabkhas 3, Kumarpahar 2, Kaitki 1, Jalibandha 7, Soniapaduka 6, Varatbhog 1, Golbhadaiya 1, Bijoo 9	94	*Nil*	Bombai, Gulabkhas, Kumarpahar, Kaitki, Jalibandha, Soniapaduka, Varatbhog, Golbhadaiya
49	B44	30	1050-1710 E.N.E.	16	Bombai 48, Langra 8, Fazli 33, Golbhadaiya 5, Zardalu 6, Hemsagar 6, Kishunbhog 9, Kumarpahar 11, Jalibandha 16, Karelwa 5, Pansera 1, Sukul 1, Sabaiya 2, Soniapaduka 5, Varatbhog 2, Kadua 1, Bijoo 4	163	*Nil*	Bombai, Fazli, Langra, Varatbhog, Bijoo
50	B45	40	1380-2040 N.E.	17	Bombai 10, Langra 12, Fazli 44, Kumarpahar 11, Kadua 5, Varatbhog 6, Sepia 3, Jalibandha 8, Golbhadaiya 3, Dilsaj 3, Zardalu 1, Kachmahua 2, Kalasar 1, Arhulwa 1, Sabaiya 8, Totapari 1, Soniapaduka 1, Bijoo 47	162	*Nil*	Soniapaduka, Sabaiya, Arhulwa, Kalasar, Kachmahua, Zardalu, Dilsaj, Jalibandha
51	B46	50	1780-2110 N.E.	...	Bijoo 56	56	*Nil*	
52	B47	30	1950-2670 N.E.	11	Bombai 3, Langra 14, Fazli 39, Kumarpahar 18, Zardalu 7, Sabaiya 1, Gulabkhas 1, Golbhadaiya 5, Hemsagar 1, Dudhia 1, Pansera 1, Bijoo 1	92	*Nil*	Kumarpahar, Zardalu, Sabaiya, Gulabkhas, Golbhadaiya, Bombai, Dudhia, Pansera
53	B48	50	2140-2610 N.E.	...	Bijoo 65	65	*Nil*	
54	B49	50	2210-2470 N.E.	...	Bijoo 23	23	*Nil*	
55	B50	40	1850-2670 N.N.E. & N.E.	11	Bombai 62, Langra 6, Fazli 11, Jalibandha 25, Soniapaduka 5, Dilsaj 3, Golbhadaiya 2, Hemsagar 1, Kumarpahar 2, Kishunbhog 2, Arhulwa 1, Bijoo 5	125	*Nil*	Jalibandha, Fazli, Bombai, Golbhadaiya, Hemsagar, Langra, Arhulwa, Bijoo
56	B51	25	1810-2200 N.N.E.	10	Bombai 69, Langra 14, Fazli 7, Kumarpahar 7, Zardalu 2, Sabaiya 2, Varatbhog 10, Hemsagar 3, Jalibandha 3, Golbhadaiya 1, Bijoo 9	127	*Nil*	Varatbhog, Sabaiya, Zardalu, Kumarpahar, Fazli, Langra, Jalibandha, Golbhadaiya Bijoo
57	B52	30	1810-2470 N. .	10	Bombai 32, Langra 3, Fazli 2, Varatbhog 3, Zardalu 1, Sabaiya 3, Jalibandha 2, Gulabkhas 1, Golbhadaiya 2, Soniapaduka 2, Bijoo 1	52	*Nil*	Langra, Fazli, Varatbhog, Zardal u,Jalibandha, Gulabkhas, Golbhadaiya, Soniapaduka, Bijoo
58	B53	35	2140-2540 N.N.E.	14	Bombai 185, Langra 3, Fazli 7, Varatbhog 10, Gopalbhog 7, Mohanbhog 9, Sabaiya 10, Kishunbhog 1, Zardalu 1, Kumarpahar 3, Kadua 2, Golbhadaiya 4, Jalibandha 1, Soniapaduka 1	194	*Nil*	Fazli, Bombai, Varatbhog, Sabaiya, Kishunbhog, Zardalu, Langra, Kumarpahar, Kadua, Golbhadaiya, Jalibandha, Soniapaduka

APPENDIX B—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
59	B54	35	2410-2540 N. & N.N.E.	3	Bombai 1, Fazli 8, Mandrasi 4	13	*Nil*	Fazli, Bombai, Mandraji
60	B55	40	490-1480 N., N. N.E., N.E. & E.N.E.	11	Bombai 4, Langra 2, Fazli 12, Hemsagar 24, Jalibandha 10, Sukul 1, Mohanbhog 2, Sabaiya 1, Dilsaj 1, Dudhia 2, Kumarpahar 3, Bijoo 1	63	Hemsagar	Fazli, Sukul, Jalibandha, Langra
61	C1	15	360-560 S.S.W.	9	Bombai 4, Langra 24, Fazli 9, Zardalu 6, Hemsagar 5, Kadua 3, Golbhadaiya 1, Jalibandha 1, Varatbhog 2, Bijoo 5	60	*Nil*	Langra, Fazli, Zardalu, Hemsagar, Kadua, Bombai, Golbhadaiya, Jalibandha, Varatbhog, Bijoo
62	C2	20	560-1050 S.S.W.	21	Bombai 20, Langra 23, Fazli 41, Zardalu 7, Kumarpahar 3, Dilsaj 1, Sabaiya 14, Banka 1, Jalibandha 3, Varatbhog 2, Soniapaduka 1, Golbhadaiya 2, Bijoo 9	130	*Nil*	Kumarpahar, Dilsaj, Jalibandha, Soniapaduka
63	C3	30	490-1020 S.E.	7	Bombai 3, Langra 16, Fazli 9, Kumarpahar 2, Sabaiya 1, Arhulwa 1, Dilsaj 1, Bijoo 8	41	*Nil*	Bijoo
64	C4	30	630-930 S.S.E.	12	Bombai 11, Langra 8, Fazli 7, Golbhadaiya 3, Kumarpahar 2, Soniapaduka 2, Dilsaj 1, Sabaiya 4, Kadua 5, Arhulwa 1, Zardalu 2, Varatbhog 3, Bijoo 6	55	*Nil*	Bombai, Langra, Fazli, Kumarpahar, Soniapaduka, Dilsaj, Sabaiya, Kadua, Arhulwa, Zardalu, Varatbhog
65	C5	30	890-1190 S.S.E.	9	Bombai 2, Langra 9, Fazli 2, Kumarpahar 2, Rosan Tawak 1, Dilsaj 2, Kadua 1, Zardalu 2, Golbhadaiya 1, Bijoo 2	24	*Nil*	Kadua
66	C6	45	990-1260 S.S.E.	2	Bombai 10, Varatbhog 1, Bijoo 5	16	*Nil*	Varatbhog
67	C7	Grafts 10 Bijoo 25	1090-1320 S.S. W.	2	Langra 5, Fazli 1, Bijoo 23	29	*Nil*	Fazli
68	C8	35	1270-1780 S.S.E.	15	Bombai 4, Langra 18, Fazli 11, Jalibandha 2, Hirasonia 1, Kumarpahar 7, Zardalu 5, Dudhia 1, Golbhadaiya 4, Sabaiya 3, Soniapaduka 4, Kadua 3, Arhulwa 1, Mohanbhog 3, Dilsaj 2, Bijoo 18	83	*Nil*	Sabaiya, Bombai.
69	C9	40	1520-1810 S.S.E.	3	Langra 1, Kadua 1, Kumarpahar 1, Bijoo 26	29	*Nil*	Kadua
70	C10	10	1190-1400 S.S.E.	4	Bombai 2, Langra 1, Fazli 4, Golbhadaiya 1, new 1	9	*Nil*	Fazli
71	C11	>30	1220-1480 S.S.E.	5	Bombai 2, Langra 2, Fazli 4, Dilsaj 2, Zardalu 1, Bijoo 1	12	*Nil*	Fazli, Dilsaj, Zardalu, Bijoo
72	C12	10	1320-1550 S.S.E.	4	Langra 9, Fazli 2, Barmasia 1, Golbhadiya 1, Bijoo 1	14	*Nil*	Fazli, Langra, Barmasia, Golbhadiya
73	C14	45	1350-1680 S.S.E.	5	Bombai 8, Langra 7, Fazli 3, Arhulwa 5, Soniapaduka 2, Bijoo 6	31	*Nil*	Fazli, Soniapaduka
74	C15	50	1650-1880 S.	4	Bombai 1, Sabaiya 2, Arhulwa 1, Soniapaduka 1	5	*Nil*	
75	C16	15	1880-2140 S.S.E.	7	Bombai 7, Langra 2, Fazli 6, Soniapaduka 1, Kachmahua 1, Gulabkhas 2, Zardalu 6	27	*Nil*	Gulabkhas, Kachmahua, Bombai, Fazli, Langra
76	C17	15	1750-1980 S.S.E.	4	Langra 15, Fazli 6, Zardalu 1, Golbhadaiya 1	23	*Nil*	Zardalu
77	C18	25	1620-1880 S.S.E.	13	Bombai 2, Langra 6, Fazli 29, Sukul 1, Hemsagar 1, Kumarpahar 1, Kishunbhog 1, Kadua 1, Lamba Vadri 1, Gulabkhas 2, Golbhadaiya 3, Zardalu 2, Varatbhog 2, new 3, Bijoo 3	58	*Nil*	Fazli, Langra, Hemsagar, Bombai, Kadua, Gulabkhas, Zardalu Varatbhog, Bijoo
78	C19	30	1650-1920 S.S.E.	...	Bijoo 9	9	*Nil*	

APPENDIX B—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
79	C20	20	760-930 S.S.W.	3	Bombai 1, Langra 6, Fazli 3 . .	10	*Nil*	Langra, Fazli, Bombai
80	D1	30	1930-2110 S.E..	...	Bijoo 4	4	*Nil*	Bijoo
81	D2	50	2080-2300 S.E..	...	Bijoo 3	3	*Nil*	Bijoo
82	D3	30	1950-2110 S.E..	...	Bijoo 3	3	*Nil*	Bijoo
83	D4	40	1480-1650 S. .	...	Bijoo 14	14	*Nil*	
84	D5	40	1260-1380 S. .	...	Bijoo 1	1	*Nil*	
85	D6	35	460-690 S. .	...	Bijoo 14	14	*Nil*	
86	D7	40	630-760 S.E. .	...	Bijoo 3	3	*Nil*	
87	D8	20	660-820 S.S.E. .	6	Bombai 4, Langra 4, Fazli 3, Zardalu 1, Sabaiya 1, Kumarpahar 1, Bijoo 2	16	*Nil*	Fazli, Bombai
88	D9	35	1020-1220 S.E. & E.S.E.	...	Bijoo 4	4	*Nil*	
89	D10	40	1020-1190 E.S.E. & S.E.	...	Bijoo 1	1	*Nil*	Bijoo
90	D11	50	2080-2370 S.E.	...	Bijoo 30	30	*Nil*	Bijoo
91	D12	50	200-560 S.E. & S.S.E.	...	Bijoo 6	6	*Nil*	Bijoo
92	D13	40	630-820 S. .	...	Bijoo 3	3	*Nil*	Bijoo
93	D14	40	1120-1260 S. .	...	Bijoo 4	4	*Nil*	
94	D15	35	1230-1290 E.S.E.	...	Bijoo 5	5	*Nil*	Bijoo
95	D16	30	2310-2440 S.E..	...	Bijoo 2	2	*Nil*	Bijoo
96	D17	30	1880-2110 S.E..	...	Bijoo 2	2	*Nil*	Bijoo
97	D18	40	1090-1220 S.E. & S.S.E.	...	Bijoo 1	1	*Nil*	
98	K1	45	1420-1810 E.S.E.	11	Bombai 34, Langra 14, Fazli 16, Dudhia 2, Kumarpahar 5, Soniapaduka 4, Golbhadaia 8, Varatbhog 4, Kishunbhog 4, Kadua 1, Sabaiya 1, Bijoo 21	114	*Nil*	
99	K2	40	960-1810 E.S.E.	...	Bijoo 59	59	*Nil*	
100	K3	40	1880-2010 E.S.E.	...	Bijoo 10	10	*Nil*	
101	K4	20	1920-2010 S.E..	1	Fazli 4, Bijoo 4	8	*Nil*	Fazli
102	K5	35	2580-2910 E.S.E.	6	Bombai 1, Langra 23, Fazli 92, Kumarpahar 3, Zardalu 4, Varatbhog 1, Bijoo 6	130	*Nil*	
103	K6	10	2080-2370 S.E..	6	Bombai 9, Langra 16, Fazli 20, Kumarpahar 1, Darma 2, Zardalu 1, Bijoo 5	54	*Nil*	Kumarpahar, Zarda
104	L1	15	390-690 E. & E.S.E.	5	Bombai 10, Langra 8, Fazli 21, Zardalu 18, new 4, Bijoo 7	68	Bombai, Zardalu, Fazli, Langra, Bijoo	new
105	L3	6	160-460 N.W., N.N.W. & N.	5	Bombai 8, Langra 2, Fazli 10, Kaitki 1, Gulabkhas 1, new 1	23	Bombai . .	Langra, Kaitki, ne
106	L4	40	330-390 N.N.E.	...	Bijoo 4	4	Bijoo	
107	L5	40	330-530 N.N.E. & N.E.	...	Bijoo 14	14	Bijoo	
108	M1	10	690-820 W. .	1	Fazli 1, Bijoo 14	5	Bijoo . .	Fazli
109	M2	40	820-890 W. .	...	Bijoo 1	1	Bijoo	
110	M3	40	460-760 W. .	...	Bijoo 1	1	Bijoo	

APPENDIX B—*contd.*

No.	Plot No.	Age of plantations (in years)	Minimum and maximum distances (in ft.) and directions from an operating brick-kiln	Number of varieties	Number of trees in each variety	Total number of trees	Black-tip	No fruits
111	M4	25	720-1150 W. & W.S.W.	5	Bombai 2, Langra 1, Fazli 1, Golbhadaiya 2, Barmasia 1	7	Bombai, Golbhadaiya, Langra	Fazli, Barmasia
112	M5	20	1350-1710 S.W.	6	Bombai 4, Langra 4, Fazli 6, Zardalu 4, Varatbhog 1, Kaitki 1	20	Zardalu, Bombai	
113	M6	40	300-1090 W.N.W. & N.W.	1	Bombai 3, Bijoo 5 . . .	8	*Nil*	Bombai
114	M7	4	160-360 S.S.W..	4	Bombai 4, Langra 4, Fazli 4, Zardalu 2, Bijoo 7	21	*Nil*	Bombai, Langra, Fazli, Zardalu, Bijoo
115	M8	40	330-660 E.N.E.	...	Bijoo 2	2	*Nil*	
116	T1	25	430-930 E.N.E.	10	Bombai 8, Langra 13, Fazli 15, Kumarpahar 1, Zardalu 8, Darma 1, Mohanbhog 3, Varatbhog 5, Kaitki 1, Jalibandha 1, new 5, Bijoo 12	73	Zardalu, Mohanbhog, Varatbhog, Bijoo	new
117	T2	30	690-1050 E. .	10	Bombai, 9, Langra 15, Fazli 11, Darma 2, Varatbhog 2, Mohanbhog 2, Jalsain 1, Karelwa 3, Sukul 1, Banka 2, new 9, Bijoo 1	58	Sukul, Darma, Varatbhog	Jalsain, new, Bijoo
118	T3	4	630-960 E. .	4	Bombai 6, Langra 22, Fazli 2, Hemsagar 1, new 2	33	Hemsagar . .	Bombai, Fazli, new
119	T4	35	610-930 E.S.E..	5	Bombai 38, Langra 5, Fazli 2, Zardalu 1, Kumarpahar 1, Bijoo 1	48	Bombai, Zardalu	
120	T5	45	930-1620 E. & E.S.E.	15	Bombai 17, Langra 42, Fazli 92, Sabaiya 6, Paduka 5, Dudhia 5, Kishunbhog 2, Jalsain 4, Jalibandha 8, Chauria 1, Sabaiya 10, Kumarpahar 5, Varatbhog 3, Zardalu 2, Golbhadaiya 1, Bijoo 17	220	Bombai	
121	T6	35	1480-1680 E. .	4	Bombai 1, Langra 5, Fazli 11, Golbhadaiya 2, Bijoo 5	24	*Nil*	Bombai, Fazli
122	T7	40	1450-1620 E. .	...	Biju 7	7	*Nil*	Bijoo
123	T8	25	1740-1810 E. .	1	Fazli 2, Biju 1	3	*Nil*	Fazli
124	T9	5	1550-1780 E. .	4	Bombai 3, Langra 6, Fazli 3, Zardalu 1, new 3	16	Zardalu . .	Bombai, Langra, Fazli, new
125	T10	35	1620-2110 E. .	...	Bijoo 27	27	*Nil*	
126	T11	20	2040-2140 E.	4	Langra 2, Fazli 4, Varatbhog 1, Golbhadaiya 1, Bijoo 2	10	*Nil*	Langra, Fazli, Varatbhog, Golbhadaiya, Bijoo
127	T12	40	2110-2250 E. .	...	Bijoo 7	7	*Nil*	Bijoo
128	T13	35	1810-1980 E.S.E.	...	Bijoo 2	2	*Nil*	
129	T14	40	1780-1810 E.S.E.	...	Bijoo 5	5	*Nil*	
130	T15	40	1810-2040 E.S.E.	...	Bijoo 6	6	*Nil*	
131	T16	40	2080-2140 E.S.E.	...	Bijoo 6	6	*Nil*	

PLANT QUARANTINE NOTIFICATIONS

Notice No. 1 of 1943

THE following plant quarantine regulations and import restrictions have been received in the Imperial Council of Agricultural Research. Those interested are advised to apply to the Secretary, Imperial Council of Agricultural Research, New Delhi, for loan.

United States Department of Agriculture

I. *Domestic Quarantine Notices*

(*i*) White Fringed Beetle Quarantine—Revision

(*ii*) Mexican Border Regulations—Revision

(*iii*) Dutch-Elm Disease Quarantine—Revision

II. *Summaries of Plant Qurantine Impo Restrictions*

(*i*) Republic of Peru—Regulations governin the importation of coffee and the introduction c parasitic insects.

(*ii*) Republic of Peru—Regulating the cultiva tion of flax in Peru and the importation of fla seed.

(*iii*) Belgian Congo—Banana Plants—Impor subject to quarantine permit.

(*iv*) Jamaica, British West Indies—Cotton lir or seed—Restricted importation permitted.

III. *Service and Regulatory Announcement- January-March 1942*

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